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Albarede

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(54) **CHAMBER MATCHING FOR POWER CONTROL MODE**

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H05H 1/46	(2006.01)
H01J 37/32	(2006.01)

(52) **U.S. Cl.**
CPC ***H05H 1/46*** (2013.01); ***H01J 37/32183*** (2013.01); ***H01J 37/32899*** (2013.01); *H05H 2001/4682* (2013.01)

(58) **Field of Classification Search**
CPC H01J 37/32
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,377,961	A	3/1983	Bode
4,420,790	A	12/1983	Golke et al.

(Continued)

FOREIGN PATENT DOCUMENTS

JP	2001-127045 A	5/2001
JP	2004239211 A	8/2004

(Continued)

OTHER PUBLICATIONS

Lars Christoph Comparison of Applied Materials DPS chambers used for poly-Si Etch process by plasma parameters Jun. 12, 2000 2nd workshop on Self excited electron plasma resonance spectroscopy Dredsen Germany.*

(Continued)

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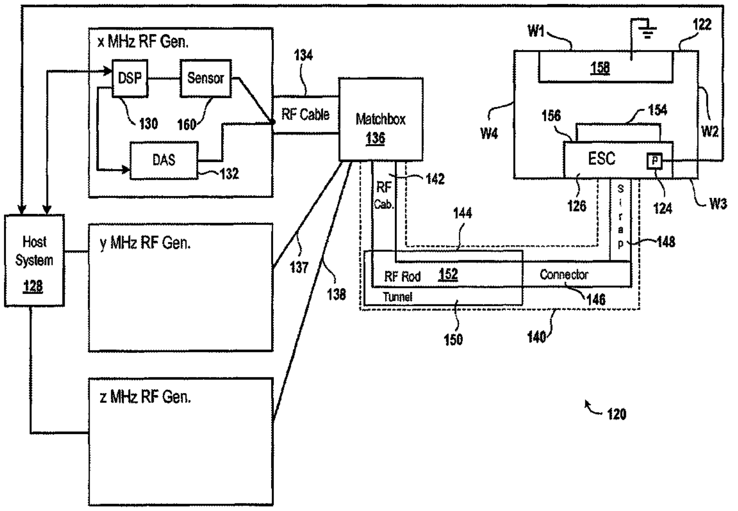
(57) **ABSTRACT**

Systems and methods for performing chamber matching are described. One of the methods for performing chamber matching includes executing a first test within a first plasma chamber to measure a variable and executing a second test within a second plasma chamber to measure the variable. The first and second tests are executed based on one recipe. The method further includes determining a first relationship between the variable measured with the first test and power provided during the first test, determining a second relationship between the variable measured with the second test and power provided during the second test, and identifying power adjustment to apply to the second plasma chamber during a subsequent processing operation based on the first and second relationships. The power adjustment causes the second plasma chamber to perform the processing operation in a processing condition determined using the first plasma chamber.

24 Claims, 8 Drawing Sheets



(56) References Cited

U.S. PATENT DOCUMENTS

4,454,001	A	6/1984	Stemheim et al.	
4,500,563	A	2/1985	Ellenberger et al.	
5,474,548	A	12/1995	Knopp et al.	
5,479,340	A	12/1995	Fox et al.	
5,556,549	A	9/1996	Patrick et al.	
5,571,366	A *	11/1996	Ishii et al.	156/345.26
5,689,215	A	11/1997	Richardson et al.	
5,694,207	A	12/1997	Hung et al.	
5,737,177	A	4/1998	Mett et al.	
5,764,471	A	6/1998	Burkhart	
5,788,801	A	8/1998	Barbee et al.	
5,810,963	A	9/1998	Tomioka	
5,812,361	A	9/1998	Jones et al.	
5,866,985	A	2/1999	Coultas et al.	
5,889,252	A	3/1999	Williams et al.	
5,892,198	A	4/1999	Barnes et al.	
5,894,400	A	4/1999	Graven et al.	
5,980,767	A	11/1999	Koshimizu et al.	
5,989,999	A *	11/1999	Levine et al.	438/627
6,020,794	A	2/2000	Wilbur	
6,021,672	A	2/2000	Lee	
6,042,686	A	3/2000	Dible et al.	
6,048,435	A	4/2000	DeOrnellas et al.	
6,110,214	A	8/2000	Klimasauskas	
6,157,867	A *	12/2000	Hwang et al.	700/121
6,198,616	B1	3/2001	Dahimene et al.	
6,246,972	B1	6/2001	Klimasauskas	
6,472,822	B1	10/2002	Chen et al.	
6,522,121	B2	2/2003	Coumou	
6,535,785	B2	3/2003	Johnson et al.	
6,597,002	B1	7/2003	Kondo	
6,669,783	B2	12/2003	Sexton et al.	
6,677,246	B2	1/2004	Scanlan et al.	
6,750,711	B2	6/2004	Chawla et al.	
6,781,317	B1 *	8/2004	Goodman	315/111.21
6,823,815	B2	11/2004	Han et al.	
6,838,635	B2	1/2005	Hoffman et al.	
6,862,557	B2	3/2005	Jones et al.	
6,873,114	B2	3/2005	Avoyan et al.	
6,972,524	B1	12/2005	Marakbtanov et al.	
6,983,215	B2	1/2006	Coumou et al.	
7,042,311	B1	5/2006	Hilliker et al.	
7,122,965	B2 *	10/2006	Goodman	315/111.21
7,169,625	B2	1/2007	Davis et al.	
7,323,116	B2	1/2008	Guiney et al.	
7,359,177	B2	4/2008	Yang et al.	
7,375,038	B2	5/2008	Kumar	
7,435,926	B2 *	10/2008	Jafarian-Tehrani	219/121.59
7,459,100	B2	12/2008	Kiemasz et al.	
7,480,571	B2	1/2009	Howald et al.	
7,505,879	B2	3/2009	Tomoyasu et al.	
7,728,602	B2	6/2010	Valcore et al.	
7,764,140	B2 *	7/2010	Nagarkatti et al.	333/17.3
7,768,269	B2	8/2010	Pipitone et al.	
7,858,898	B2	12/2010	Bailey, III et al.	
7,967,944	B2	6/2011	Shannon et al.	
8,040,068	B2	10/2011	Coumou et al.	
8,080,168	B2	12/2011	Cirigliano	
8,080,760	B2	12/2011	Dhindsa et al.	
8,103,492	B2 *	1/2012	Brcka	703/6
8,264,238	B1	9/2012	El-Chouelry	
8,271,121	B2	9/2012	Venugopal et al.	
8,368,308	B2	2/2013	Banna et al.	
8,404,598	B2	3/2013	Liao et al.	
8,501,631	B2	8/2013	Valcore et al.	
8,901,935	B2	12/2014	Valcore et al.	
2003/0082835	A1	5/2003	McChesney et al.	
2003/0103793	A1	6/2003	Murakoshi et al.	
2004/0028837	A1	2/2004	Fink	
2004/0045506	A1	3/2004	Chen et al.	
2004/0060660	A1 *	4/2004	Klimecky et al.	156/345.28
2004/0061448	A1	4/2004	Avoyan et al.	
2004/0087047	A1	5/2004	Jaiswal et al.	
2004/0107906	A1	6/2004	Collins et al.	
2004/0135590	A1	7/2004	Quon	
2004/0222184	A1	11/2004	Hayami et al.	
2004/0226657	A1	11/2004	Hoffman	
2005/0057165	A1 *	3/2005	Goodman	315/111.51
2005/0090118	A1	4/2005	Shannon et al.	
2005/0133163	A1	6/2005	Shannon et al.	
2005/0134186	A1	6/2005	Brouk et al.	
2005/0151479	A1	7/2005	Avoyan et al.	
2005/0217797	A1 *	10/2005	Jafarian-Tehrani	156/345.28
2005/0241762	A1	11/2005	Paterson et al.	
2005/0252884	A1	11/2005	Lam et al.	
2006/0065623	A1	3/2006	Guiney et al.	
2006/0065631	A1	3/2006	Cheng et al.	
2006/0065632	A1	3/2006	Cheng et al.	
2006/0088655	A1	4/2006	Collins et al.	
2006/0100824	A1	5/2006	Moriya	
2006/0169582	A1	8/2006	Brown et al.	
2006/0231526	A1	10/2006	Donohue	
2006/0232471	A1	10/2006	Coumou	
2007/0021935	A1	1/2007	Larson et al.	
2007/0065594	A1	3/2007	Chiang et al.	
2007/0247074	A1	10/2007	Paterson et al.	
2007/0252580	A1	11/2007	Dine et al.	
2007/0262723	A1	11/2007	Ikenouchi	
2009/0151871	A1	6/2009	Pease et al.	
2009/0284156	A1	11/2009	Banna et al.	
2009/0294061	A1	12/2009	Shannon et al.	
2009/0295296	A1	12/2009	Shannon et al.	
2010/0099266	A1	4/2010	Oswald et al.	
2010/0270141	A1	10/2010	Carter et al.	
2010/0332201	A1 *	12/2010	Albarede et al.	703/2
2011/0031216	A1	2/2011	Liao et al.	
2011/0097901	A1	4/2011	Banna et al.	
2011/0115492	A1	5/2011	Valcore, Jr. et al.	
2011/0118863	A1	5/2011	Valcore, Jr.	
2011/0137446	A1	6/2011	Valcore, Jr. et al.	
2012/0073754	A1	3/2012	De la Llera et al.	
2012/0187844	A1 *	7/2012	Hoffman et al.	315/111.51
2012/0262064	A1 *	10/2012	Nagarkatti et al.	315/111.21
2014/0062303	A1 *	3/2014	Hoffman et al.	315/111.21

FOREIGN PATENT DOCUMENTS

JP	2004-335594	A	11/2004
JP	2005130198	A	5/2005
JP	2005284046	A	10/2005
KR	10-2005-0088438	A	9/2005
KR	10-2005-0089995	A	9/2005
KR	10-2007-0031915	A	3/2007
WO	2008002938	A2	1/2008
WO	2012054306	A2	4/2012

OTHER PUBLICATIONS

Christoph Steuer TOOL Comparison at GC stack Etch in LAM TCP Using Plasma Parameters (SEERS) Dec. 12, 2000 2nd workshop on self excited electron plasma resonance Sepectroscopy Germany.*

Thorsten, Lill et al., "Controlling Ion Energy Within a Plasma Chamber", U.S. Appl. No. 13/930,138, filed Jun. 28, 2013.

Electromagnetic Waves and Antennas, Sophocles J. Orfanidis, Rutgers University, Aug. 25, 2013, Chapter 10.10.

Darnon et al., "Synchronous Pulsed Plasma for Silicon Etch Applications", ECS Transactions, 27 (1) pp. 717-723 (2010), Publication by: The Electrochemical Society.

PCT/US2010/057478 International Search Report and Written Opinion, mailed Jul. 26, 2011 (6 pages).

PCT/US2011/063422 International Search Report and Written Opinion, mailed Mar. 28, 2012 (9 pages).

PCT/US2010/057450 International Search Report and Written Opinion, mailed Jul. 18, 2011 (9 pages).

PCT/IB2013/051010 International Search Report and Written Opinion, mailed Jul. 3, 2013 (13 pages).

* cited by examiner

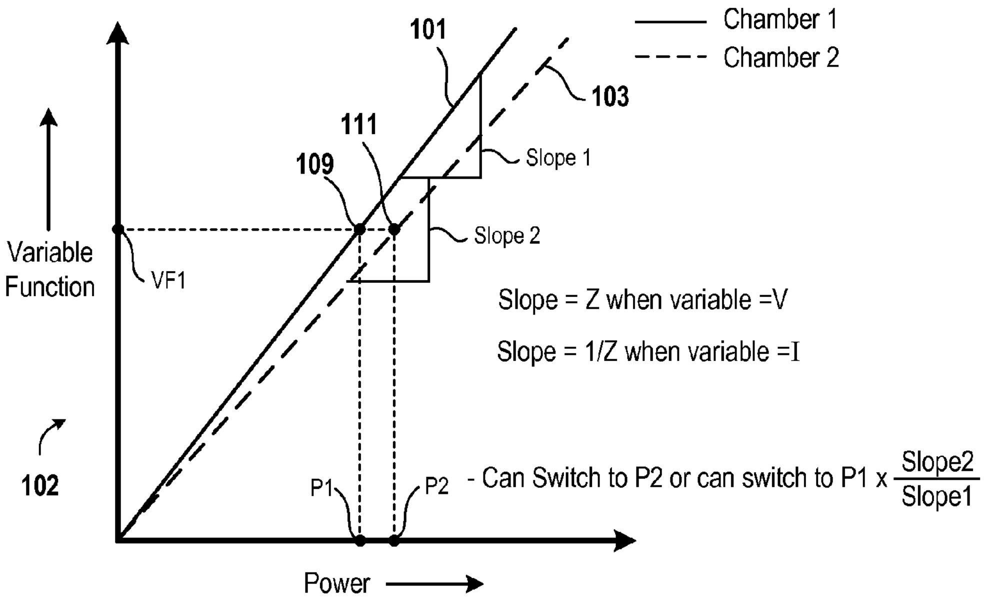

Chamber 1
Chamber 2
101
103
111
109
Slope 1
Slope 2
Variable Function
VF1
Slope = Z when variable =V
Slope = 1/Z when variable =I
102
P1
P2
- Can Switch to P2 or can switch to P1 x Slope2/Slope1
Power

FIG. 1

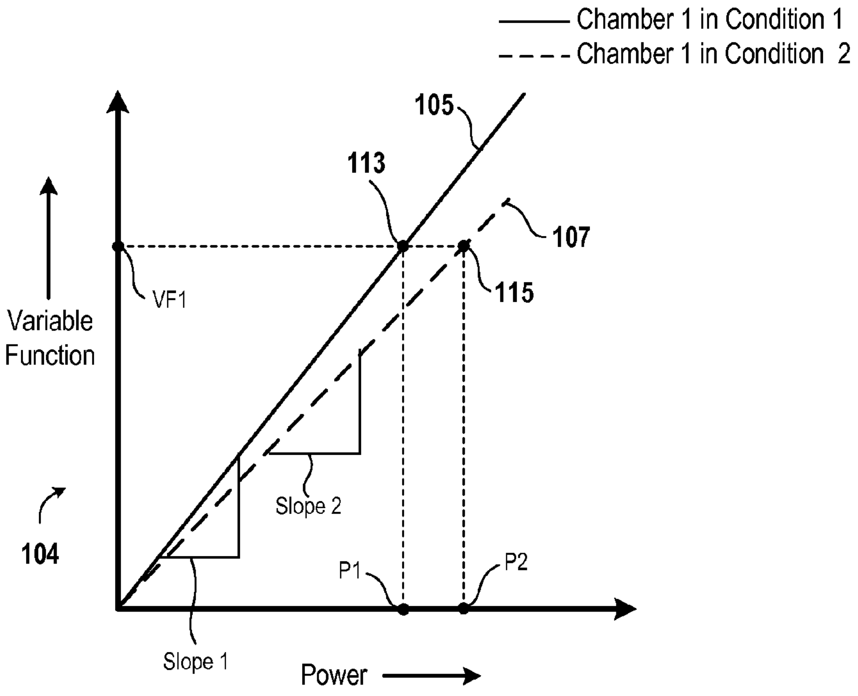

Chamber 1 in Condition 1
Chamber 1 in Condition 2
105
113
107
115
VF1
Variable Function
Slope 2
104
P1
P2
Slope 1
Power

FIG. 2

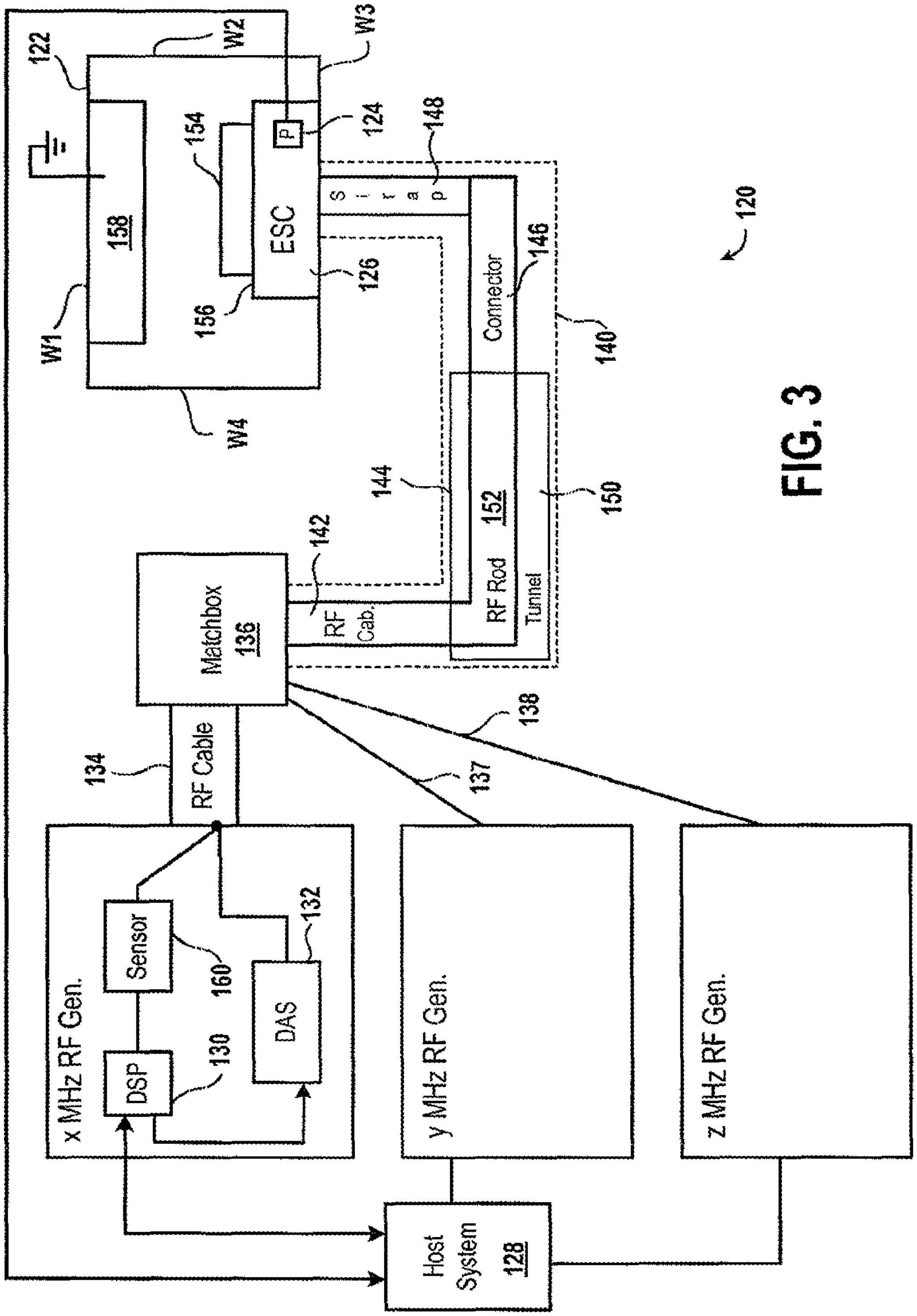

122
W2
W3
158
154
P
124
148
ESC
Strap
W1
156
126
146
Connector
140
120
W4
144
152
150
RF Rod
Tunnel
142
RF Cab.
Matchbox
136
138
134
RF Cable
137
Sensor
132
160
DAS
130
DSP
x MHz RF Gen.
y MHz RF Gen.
z MHz RF Gen.
Host System
128

FIG. 3

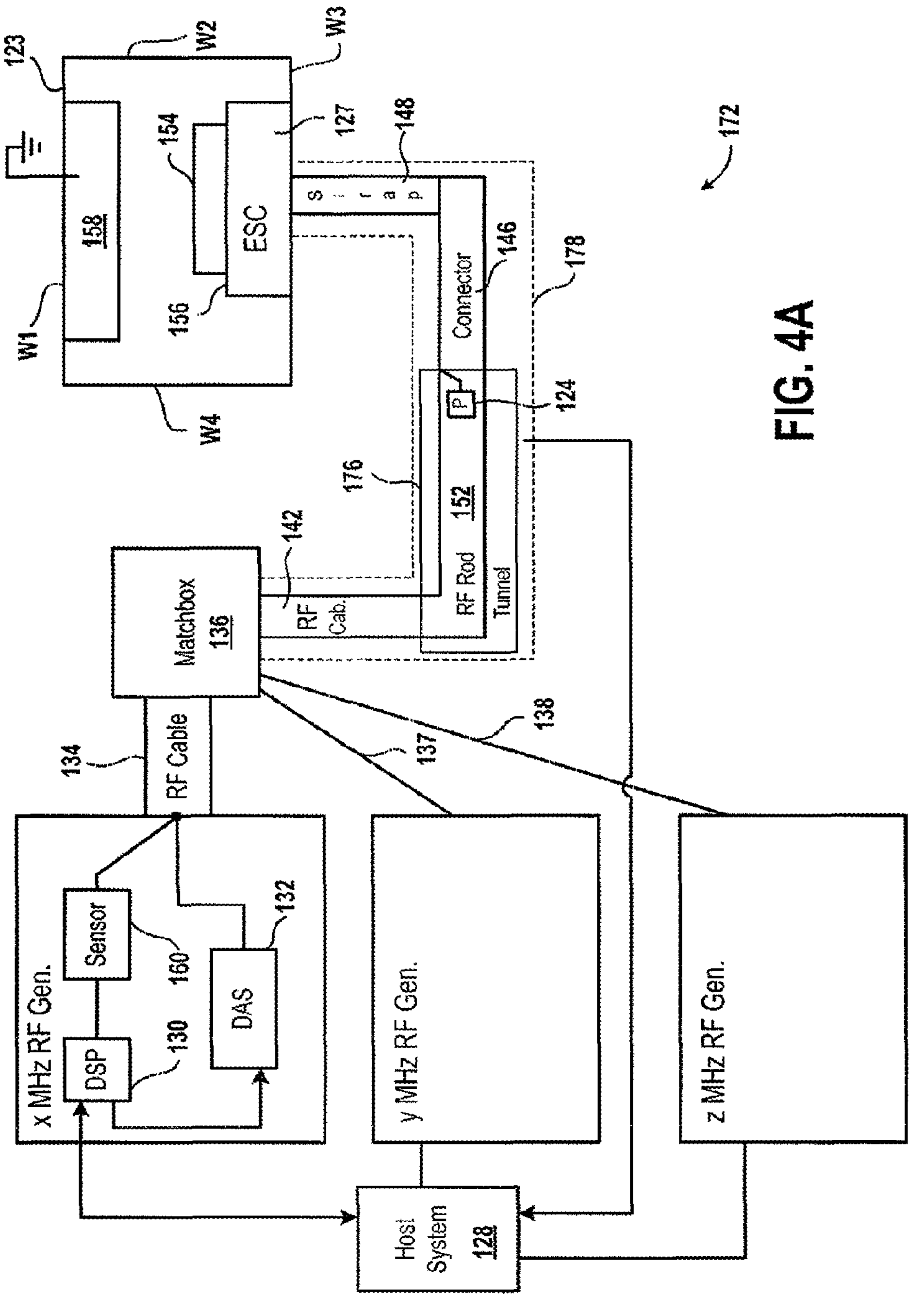

123
W2
W3
W1
W4
158
154
ESC
156
127
148
Strap
Connector
146
178
172
P
124
152
RF Rod
Tunnel
176
142
RF Cab.
Matchbox
136
134
RF Cable
137
138
x MHz RF Gen.
Sensor
160
DSP
130
DAS
132
y MHz RF Gen.
z MHz RF Gen.
Host System
128

FIG. 4A

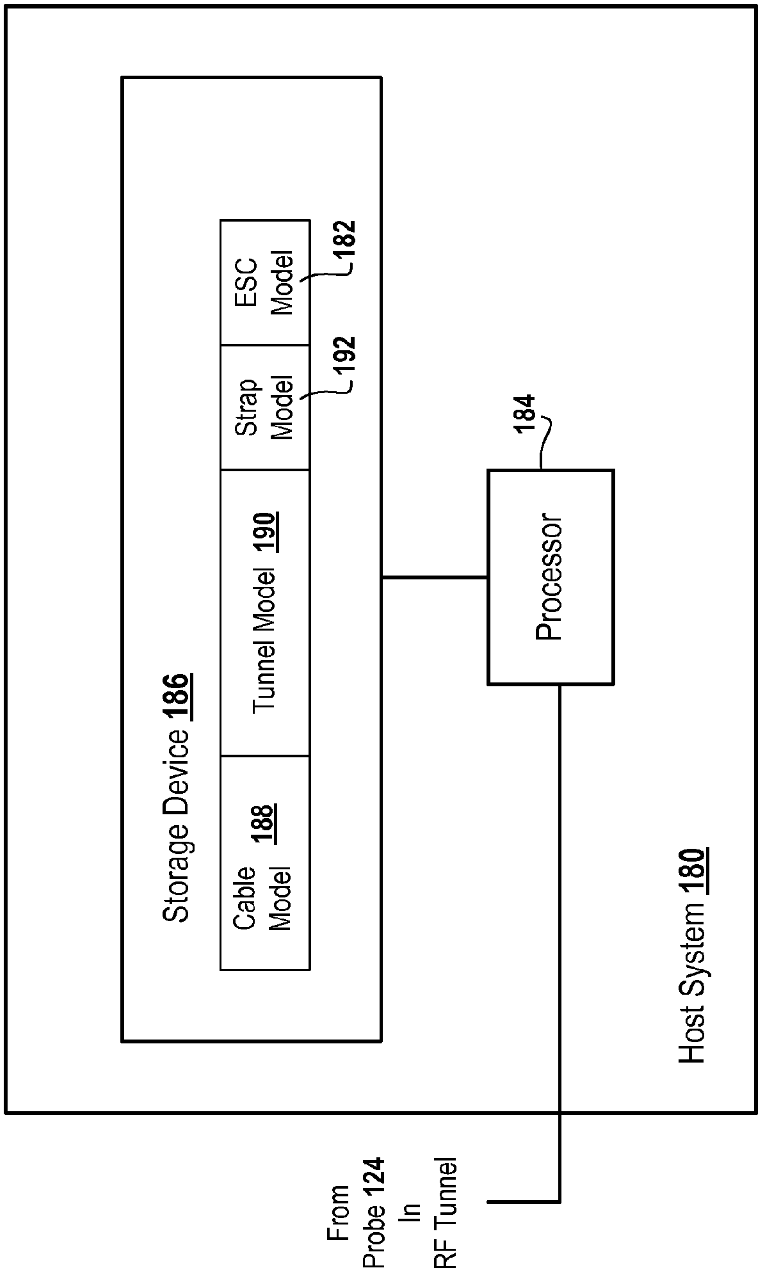

Storage Device 186
Cable Model 188
Tunnel Model 190
Strap Model
192
ESC Model
182
Processor
184
Host System 180
From Probe 124 In RF Tunnel

FIG. 4B

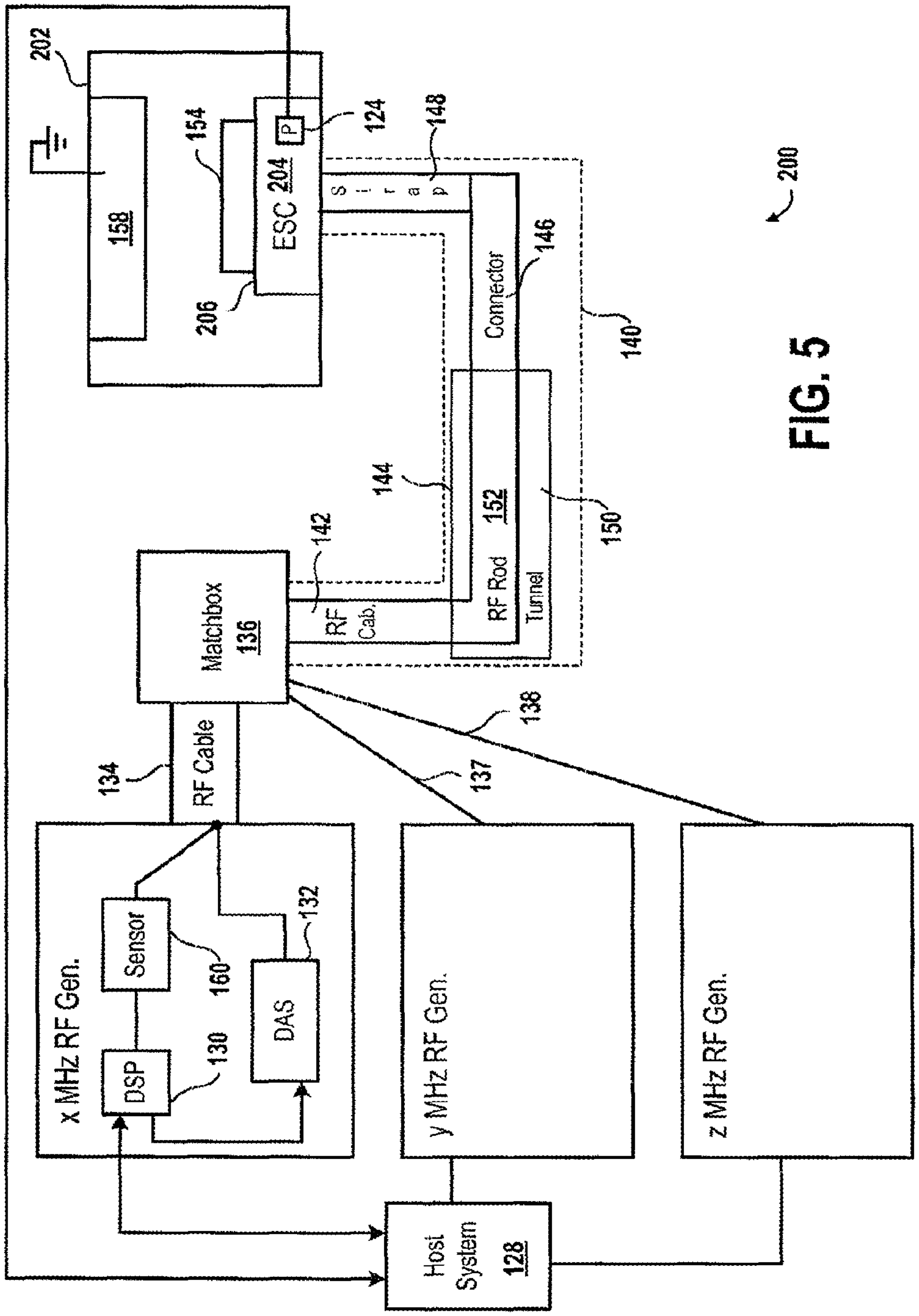

200
202
158
154
ESC 204
P
124
148
Strap
206
146
Connector
140
144
142
RF Cab.
RF Rod 152
Tunnel
150
Matchbox 136
138
137
134
RF Cable
x MHz RF Gen.
Sensor
160
132
DAS
DSP
130
y MHz RF Gen.
z MHz RF Gen.
Host System 128

FIG. 5

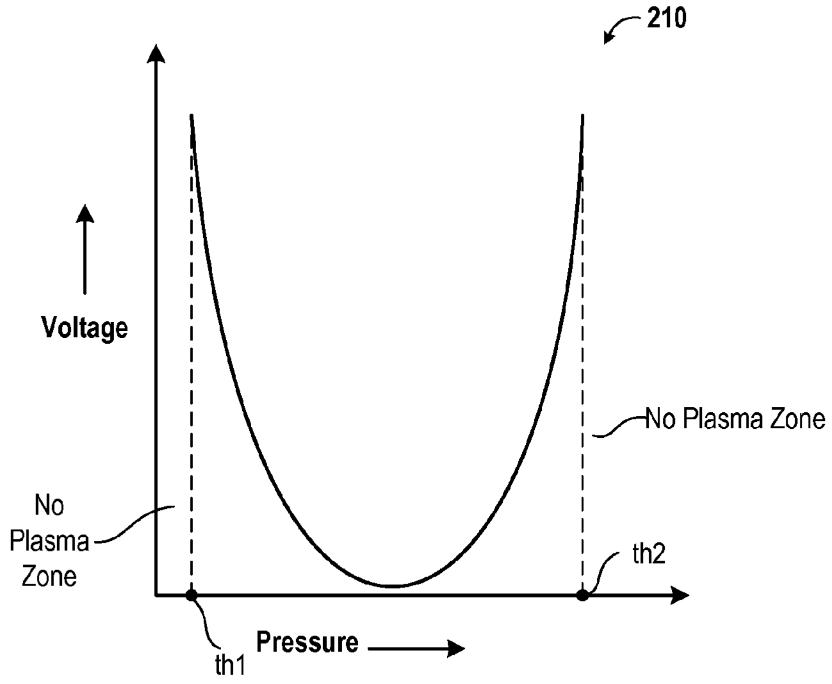
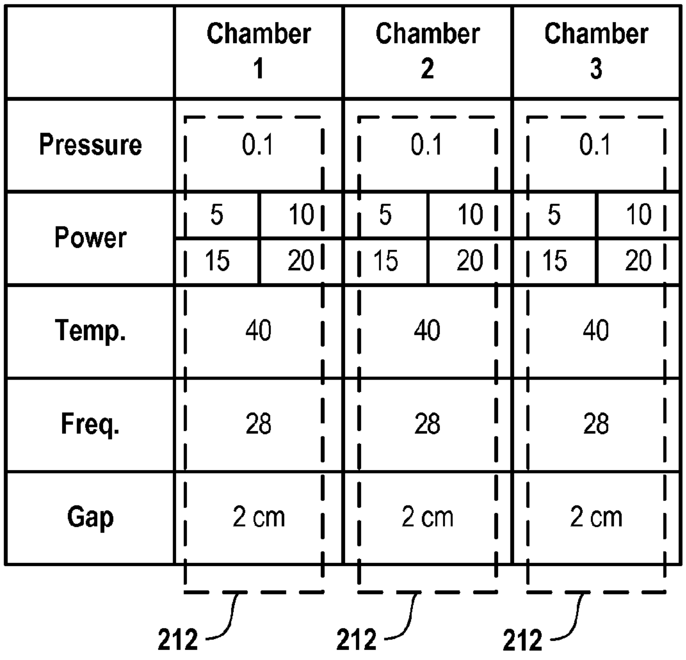
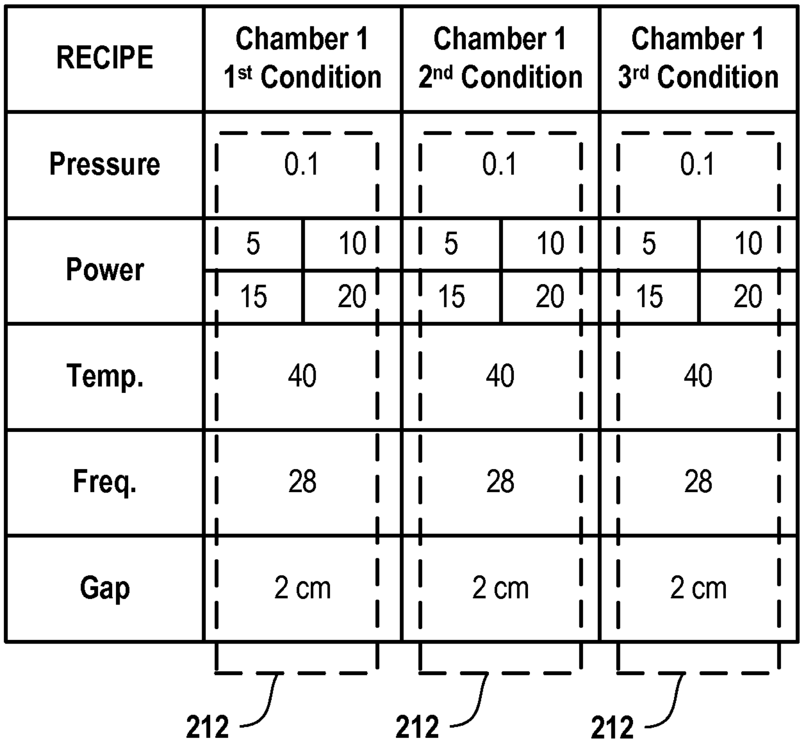


FIG. 6



	Chamber 1	Chamber 2	Chamber 3
Pressure	0.1	0.1	0.1
Power	5 10 15 20	5 10 15 20	5 10 15 20
Temp.	40	40	40
Freq.	28	28	28
Gap	2 cm	2 cm	2 cm

FIG. 7



RECIPE	Chamber 1 1st Condition	Chamber 1 2nd Condition	Chamber 1 3rd Condition
Pressure	0.1	0.1	0.1
Power	5 10 15 20	5 10 15 20	5 10 15 20
Temp.	40	40	40
Freq.	28	28	28
Gap	2 cm	2 cm	2 cm

FIG. 8

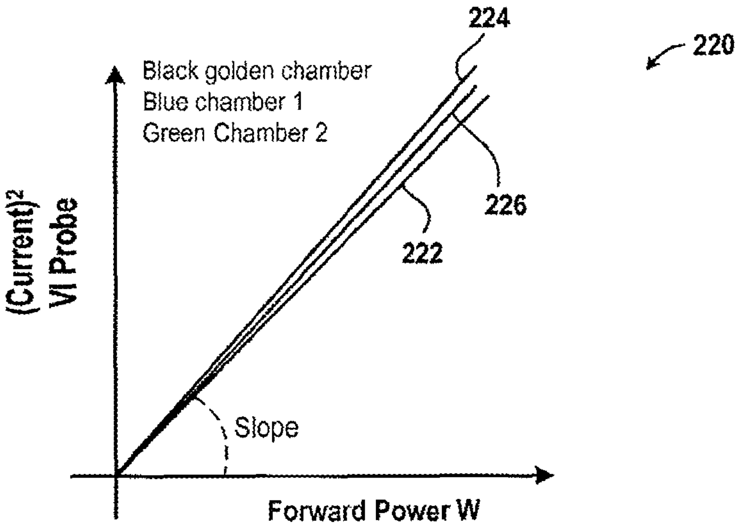

224
220
Black golden chamber
Blue chamber 1
Green Chamber 2
226
222
(Current)²
VI Probe
Slope
Forward Power W

FIG. 9A

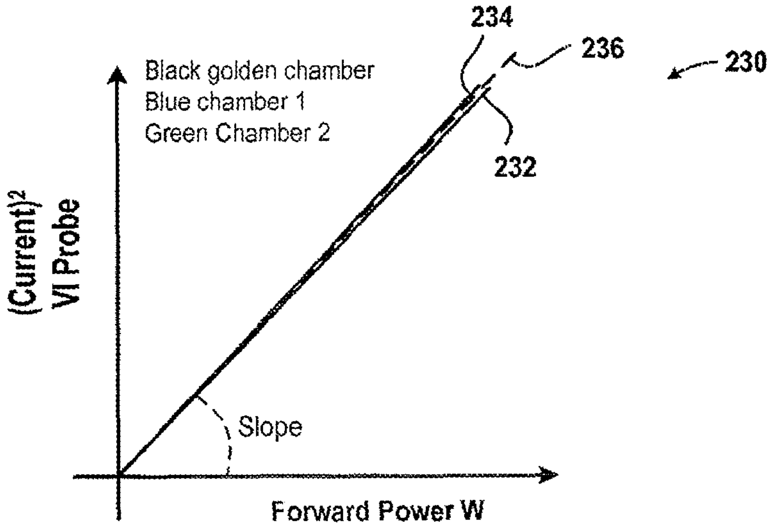

234
236
230
Black golden chamber
Blue chamber 1
Green Chamber 2
232
(Current)²
VI Probe
Slope
Forward Power W

FIG. 9B

CHAMBER MATCHING FOR POWER CONTROL MODE

CLAIM OF PRIORITY

This application claims the benefit of and priority to, under 35 U.S.C. 119§(e), to U.S. Provisional Patent Application No. 61/784,086, filed on Mar. 14, 2013, and titled "Chamber Matching Using a Power Control Mode", which is hereby incorporated by reference in its entirety.

FIELD

The present embodiments relate to chamber matching using a power control mode.

BACKGROUND

Plasma chambers are used for a variety of purposes. For example, plasma is generated within a plasma chamber to etch a substrate, clean a substrate, deposit layers on the substrate, or perform other processes on the substrate.

Various chambers are used to process the substrate. Also, the same chamber is used to process the substrate. When different chambers are used, the substrate may not be processed in a substantially uniform manner. For example, a substrate etched using one plasma chamber may be etched at a different rate than another substrate that is etched using another plasma chamber. As another example, a substantially higher amount of material may be deposited on a substrate processed in a plasma chamber than that deposited on the substrate in another plasma chamber.

It is in this context that embodiments described in the present disclosure arise.

SUMMARY

Embodiments of the disclosure provide apparatus, methods and computer programs for chamber matching using a power control mode. It should be appreciated that the present embodiments can be implemented in numerous ways, e.g., a process, an apparatus, a system, a device, or a method on a computer-readable medium. Several embodiments are described below.

In some embodiments, a method for performing chamber-to-chamber matching is described. The method includes executing a first test within a first plasma chamber to measure a variable and executing a second test within a second plasma chamber to measure the variable. The first and second tests are executed based on one recipe. The method further includes determining a first relationship between the variable measured with the first test and power provided during the first test, determining a second relationship between the variable measured with the second test and power provided during the second test, and identifying power adjustment to apply to the second plasma chamber during a subsequent processing operation based on the first and second relationships. The power adjustment causes the second plasma chamber to perform the processing operation in a processing condition determined using the first plasma chamber.

In various embodiments, a method for performing intra-chamber matching is described. The method includes executing a first test to measure a variable associated with a plasma chamber. The plasma chamber is in a first condition during execution of the first test. The method further includes executing a second test to measure the variable associated with the plasma chamber. The plasma chamber is in a second condition during execution of the second test. The method includes determining a first relationship between the variable measured using the first test and power provided during the first test, determining a second relationship between the variable measured using the second test and power provided during the second test, and identifying power adjustment to apply to the plasma chamber during a subsequent processing operation based on the first and second relationships. The power adjustment causes the plasma chamber to perform the processing operation in a processing condition. The processing condition is determined when the plasma chamber is in the first condition.

In several embodiments, a plasma system for performing chamber-to-chamber matching is described. The plasma system includes a first plasma chamber used to execute a first test to measure a variable, a radio frequency (RF) transmission line coupled to the first plasma chamber for communicating an RF signal to the first plasma chamber, and an impedance matching circuit coupled to the RF transmission line. The plasma system further includes an RF generator coupled to the impedance matching circuit for supplying the RF signal and a second plasma chamber used to execute a second test to measure the variable. The first and second tests are executed based on one recipe. The second test is executed after decoupling the first plasma chamber from the RF transmission line and coupling the second plasma chamber to the RF transmission line. The plasma system includes a host system further including a processor. The host system is coupled to the RF generator. The processor is configured to determine a first relationship between the variable measured with the first test and power provided during the first test, determine a second relationship between the variable measured with the second test and power provided during the second test, and identify power adjustment to apply to the second plasma chamber during a subsequent processing operation based on the first and second relationships. The power adjustment causes the second plasma chamber to perform the processing operation in a processing condition determined using the first plasma chamber.

In a number of embodiments, a plasma system for performing intra-chamber matching is described. The plasma system includes a plasma chamber used to execute a first test to measure a variable. The plasma chamber is in a first condition during execution of the first test. The plasma chamber is used to execute a second test to measure the variable. Also, the plasma chamber is in a second condition during execution of the second test. The plasma system further includes a radio frequency (RF) transmission line coupled to the plasma chamber for communicating an RF signal to the plasma chamber. The plasma system further includes an impedance matching circuit coupled to the RF transmission line, an RF generator coupled to the impedance matching circuit for supplying the RF signal, and a host system including a processor, the host system coupled to the RF generator. The processor is configured to determine a first relationship between the variable measured using the first test and power provided during the first test, determine a second relationship between the variable measured using the second test and power provided during the second test, and identify power adjustment to apply to the plasma chamber during a subsequent processing operation based on the first and second relationships. The power adjustment causes the plasma chamber to perform the processing operation in a processing condition. The processing condition is determined when the plasma chamber is in the first condition.

In some embodiments, a first relationship between a function of a variable, e.g., voltage, current, etc., and power is generated. The variable is measured from a gap inside a plasma chamber and the power is power supplied to an electrode of the plasma chamber or power delivered to the electrode. Moreover, a second relationship between a function of a variable and power is generated. The second relationship may be generated using the same plasma chamber as that used to generate the first relationship or another plasma chamber than the plasma chamber used to generate the first relationship. The second relationship is compared with the first relationship to determine a difference between the first and second relationships. The difference is reduced to achieve the first relationship from the second relationship or to achieve the second relationship from the first relationship. For example, same amount of power provided to a plasma chamber that is used to generate the first relationship is provided to another plasma chamber that is used to generate the second relationship. As another example, power provided to a plasma chamber that is used to generate the first relationship is modified to achieve the second relationship. In this example, both the first and second relationships are generated using the same plasma chamber.

Some advantages of the above-described embodiments include performing chamber-to-chamber matching or intrachamber matching using a power control mode. For example, when the first relationship is modified to achieve the second relationship, the plasma chamber used to generate the first relationship is operated to achieve the second relationship. When the plasma chamber used to generate the first relationship is operated to achieve the second relationship, a substantial amount of uniformity is achieved in processing a wafer in the plasma chambers that are used to generate the first and second relationships.

Moreover, a condition of a plasma chamber used to generate the first relationship may change over time. As a result of a change in the condition, the plasma chamber used to generate the first relationship may produce different results that are visible on wafers. For example, when a wafer is cleaned in a plasma chamber used to generate the first relationship, the cleaning process changes a condition of the plasma chamber. After the cleaning, when the plasma chamber used to generate the first relationship is used to clean another wafer, the other wafer may not be cleaned to the same extent, e.g., level, aspect ratio, etc., as that of the wafer cleaned before the other wafer. The variation in processing wafers over time results in a radio frequency (RF) transmission line that is coupled the plasma chamber used to generate the first relationship experiencing different losses over time of RF power communicated over the transmission line. The modification of the first relationship to achieve the second relationship in the plasma chamber used to generate the first relationship has an advantage of reducing the non-uniformity in processing of wafers. When the modification is performed, the difference in the losses is compensated for.

Other aspects will become apparent from the following detailed description, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments may best be understood by reference to the following description taken in conjunction with the accompanying drawings.

FIG. **1** is a diagram of a graph for illustrating chamber-to-chamber matching using a power control mode, in accordance with an embodiment described in the present disclosure.

FIG. **2** is a diagram of an embodiment of a graph to illustrate intra-chamber matching using a power control mode, in accordance with an embodiment described in the present disclosure.

FIG. **3** is a block diagram of a plasma system for generating one or more relationships between a function of variable and power delivered to a plasma chamber by using a probe within an electrostatic chuck (ESC), in accordance with an embodiment described in the present disclosure.

FIG. **4**A is a block diagram of a plasma system for generating one or more relationships between the function of the variable and power delivered to a plasma chamber by using the probe within a radio frequency tunnel, in accordance with an embodiment described in the present disclosure.

FIG. **4**B is a block diagram of a host system for using a computer-generated model to determine a value of a variable at an ESC model, in accordance with an embodiment described in the present disclosure.

FIG. **5** is a block diagram of a plasma system for illustrating inter-chamber matching between a plasma chamber of the plasma system of FIG. **3** and another plasma chamber, in accordance with an embodiment described in the present disclosure.

FIG. **6** is a diagram of a graph used to illustrate a relationship between voltage and pressure during a no-plasma test, in accordance with an embodiment described in the present disclosure.

FIG. **7** shows a recipe for performing chamber-to-chamber matching, in accordance with an embodiment described in the present disclosure.

FIG. **8** shows a recipe for performing intra-chamber matching, in accordance with an embodiment described in the present disclosure.

FIG. **9**A is a diagram of a graph used to illustrate a difference in relationships between three plasma chambers, in accordance with an embodiment described in the present disclosure.

FIG. **9**B is an embodiment of a graph used to illustrate a similarity in relationships between three plasma chambers after applying several embodiments described in the present disclosure.

DETAILED DESCRIPTION

The following embodiments describe systems and methods for chamber matching using a power control mode. It will be apparent that the present embodiments may be practiced without some or all of these specific details. In other instances, well known process operations have not been described in detail in order not to unnecessarily obscure the present embodiments.

FIG. **1** is a diagram of an embodiment of a graph **102** for illustrating chamber-to-chamber matching using a power control mode. In chamber-to-chamber matching using a power control mode, a relationship between a function of a variable measured using a plasma chamber **1** and power associated with the plasma chamber **1** is determined. Also, a relationship between a function of the variable measured using a plasma chamber **2** and power associated with the plasma chamber **2** is determined.

Examples of the variable include current, voltage, reflection coefficient, etc. Examples of the function of the variable include a square of the variable, a square root of the variable, a mathematical power function of the variable, etc.

In some embodiments, the plasma chamber **2** has the same structure as that of the plasma chamber **1**. For example, the plasma chamber **2** includes elements that have same dimensions as that of corresponding elements in the plasma chamber **1**. As another example, the plasma chamber **2** includes elements that are of the same type as that of corresponding elements in the plasma chamber **1**. To illustrate, a transformer coupled plasma (TCP) chamber has one or more elements of a different type than one or more elements of an inductively coupled plasma (ICP) chamber and both the TCP and the ICP chambers have one or more elements of different types than one or more elements of an electron cyclotron resonance (ECR) plasma chamber.

Examples of elements of a plasma chamber include an upper electrode, a lower electrode, an upper plasma exclusion zone (PEZ) ring, a lower PEZ ring, a confinement ring assembly, an edge ring, an insulator layer, gas distribution apertures, walls of the plasma chamber, an upper dielectric ring surrounding the upper electrode, an upper electrode extension surrounding the upper dielectric ring, a lower dielectric ring surrounding the lower electrode, a lower electrode extension surrounding the lower dielectric ring, etc. In various embodiments, the lower electrode and the lower electrode extension are made of a metal, e.g., anodized aluminum, alloy of aluminum, etc. Also, in some embodiments, the upper electrode and the upper electrode extension are made of a metal, e.g., aluminum, alloy of aluminum, etc. In several embodiments, the upper electrode is located opposite to and facing the lower electrode and the upper electrode extension is located opposite to and facing the upper electrode.

Examples of dimensions of an element include a size of the element, a length of the element, a depth of the element, a width of the elements, a surface area of the element, a volume occupied by the element, etc.

Examples of elements of different types include a plate electrode, an electric coil electrode, etc.

In various embodiments, the plasma chamber **2** is structurally identical to plasma chamber **1** and has a different identification code than that of the plasma chamber **1**. For example, an entity identifies the plasma chamber **1** using an identity code aaaa and the entity identifies the plasma chamber **2** using an identity code bbbb.

In a number of embodiments, the plasma chamber **1** is structurally identical to the plasma chamber **2** and is used to perform the same function as that of the plasma chamber **1**. Examples of a function performed by a plasma chamber include physical vapor deposition (PVD), chemical vapor deposition (CVD), plasma-enhanced CVD (PECVD), metal CVD, a high-density plasma CVD (HDP-CVD) function, a photoresist strip function, a photoresist surface preparation, ultraviolet thermal processing (UVTP), etc.

In various embodiments, the plasma chamber **2** is structurally and functionally identical to plasma chamber **1** and has a different identification code than that of the plasma chamber **1**.

The power delivered to the plasma chamber **1** is adjusted to achieve the relationship generated using the plasma chamber **2**. In some embodiments, instead of adjusting the power delivered to the plasma chamber **1** to achieve the relationship associated with the plasma chamber **2**, the power delivered to the plasma chamber **2** is adjusted to achieve the relationship generated using the plasma chamber **1**.

In several embodiments, when the plasma chamber **1** is a golden chamber, which has a higher yield than that of the plasma chamber **2**, the power delivered to the plasma chamber **2** is adjusted to achieve the relationship generated using the plasma chamber **1**. Also, when the plasma chamber **2** is a golden chamber, which has a higher yield than that of the plasma chamber **1**, the power delivered to the plasma chamber **1** is adjusted to achieve the relationship generated using the plasma chamber **2**.

In various embodiments, a plasma chamber has a higher yield than another plasma chamber when the higher yielding plasma chamber is used to etch a wafer to achieve a higher aspect ratio than that achieved using the lower yielding plasma chamber, when use of the higher yielding plasma chamber results in wafers that are cleaner than those cleaned using the lower yielding plasma chamber, when the higher yielding plasma chamber etches at a faster rate than that achieved using the lower yielding plasma chamber, when the higher yielding plasma chamber cleans wafers at a faster rate than that achieved using the lower yielding plasma chamber, when the higher yielding plasma chamber has a higher rate of processing wafers than that of the lower yielding plasma chamber, or a combination thereof.

In the graph **102**, the function of the variable is plotted along a y-axis and power is plotted along an x-axis. In some embodiments, the power plotted along the x-axis is delivered power, which is power delivered to a plasma chamber. As an example, delivered power is a difference between supplied power and reflected power. Supplied power is power supplied to a plasma chamber by a radio frequency (RF) generator and reflected power is power reflected from the plasma chamber towards the RF generator. In various embodiments, the power plotted along the x-axis is supplied power instead of delivered power.

A solid line **101** of the graph **102** is plotted using the plasma chamber **1**. For example, the power delivered to the plasma chamber **1** is plotted along the x-axis. Moreover, a current is measured at a point on an element located between an RF generator and a wafer within the plasma chamber **1** and a square of the current is plotted along the y-axis. As another example, instead of the current, a voltage is measured at the point and a square of the voltage is plotted on the y-axis. The square of the voltage is plotted against power delivered to the plasma chamber **1** to generate the solid line **101**.

In several embodiments, a no-plasma test is performed using the plasma chamber **1** to obtain the relationship illustrated in the solid line **101**. For example, an amount of pressure is maintained below a threshold or above a threshold within the plasma chamber **1** to avoid striking plasma within the plasma chamber **1**. As another example, during the no-plasma test, an RF generator generates an RF signal that is provided via an impedance matching circuit and an RF transmission line to a lower electrode of a plasma chamber. In this example, a minimal amount of plasma is stricken within the plasma chamber.

Electrical elements that are located between an RF generator and the wafer include elements that couple the RF generator to a plasma chamber. Examples of elements between an RF generator and a wafer include an RF cable, an impedance matching circuit, an RF transmission line, and an electrostatic chuck (ESC). An RF cable couples an RF generator to an impedance matching circuit, which is coupled via an RF transmission line to an ESC of a plasma chamber.

A dashed line **103** of the graph **102** is plotted using the plasma chamber **2** in a similar manner in which the solid line **101** of the graph **102** is plotted for the plasma chamber **1**. For example, the power delivered to the plasma chamber **2** is plotted along the x-axis. Moreover, a current is measured at a point on an element located between an RF generator and a wafer within the plasma chamber **2** and a square of the current is plotted along the y-axis. As another example, instead of the current, a voltage is measured at the point and a square of the voltage is plotted on the y-axis. The square of the voltage is plotted against power delivered to the plasma chamber **2** to generate the dashed line **103**.

In several embodiments, a no-plasma test is performed using the plasma chamber **2** to obtain the relationship illustrated in the dashed line **103**. For example, an amount of pressure is maintained below a threshold or above a threshold within the plasma chamber **2** to avoid striking plasma within the plasma chamber **2**.

A line is horizontally extended from a variable function **1** (VF**1**), e.g. square of a current value, square of a voltage value, etc., past a point **109** on the solid line **101** to intersect a point **111** on the dashed line **103**. A line is vertically extended from the point **111** to a point P**2** on the x-axis. The point P**2** has a power value of P**2**.

Instead of providing, e.g., delivering, supplying, etc., a power P**1** to the plasma chamber **1** to achieve the variable function **1**, the power P**2** is provided to the plasma chamber **1** to achieve the variable function **1**. For example, to achieve the higher yield of the plasma chamber **2**, instead of providing the power P**1** to the plasma chamber **1** to achieve the variable function **1**, the power P**2** is provided to the plasma chamber **1** to achieve the variable function **1**. As another example, at a time the power P**1** is to be provided to the plasma chamber **1** to achieve the variable function **1**, the power P**2** is provided to the plasma chamber **1** to achieve the variable function **1** and to achieve the higher yield of the plasma chamber **2**. Similarly, in some embodiments, instead of providing the power P**2** to the plasma chamber **2** to achieve the variable function **1**, the power P**1** is provided to the plasma chamber **2** to achieve the variable function **1**.

In some embodiments, provided power is delivered power or supplied power.

In various embodiments, instead of extending lines horizontally and/or vertically within the graph **102** to determine the power P**2** corresponding to the variable function **1**, a slope **1** of the solid line **101** and a slope **2** of the dashed line **103** is calculated. The power P**1** that is to be provided to the plasma chamber **1** to achieve the variable function **1** is multiplied with a ratio of slope **1** and slope **2** to provide the power P**2** to the plasma chamber **1**. For example, when the higher yielding relationship, shown by the dashed line **103**, of the plasma chamber **2** is to be achieved, instead of providing the power P**1** to the plasma chamber **1** to achieve the variable function **1**, a power value, e.g., the power value P**2**, generated by multiplying the power value P**1** with the ratio of slope **1** and slope **2** is provided to the plasma chamber **1** to achieve the variable function **1**.

In some embodiments, when the relationship associated with the plasma chamber **1** is to be achieved, e.g., to achieve the higher yield of the plasma chamber **1** and to achieve the variable function **1**, the power value P**2** is multiplied by a ratio of slope **2** and slope **1** to generate the power value P**1** that is to be provided to the plasma chamber **2**.

In some embodiments, the terms "power value P**1**" and "power P**1**" are used interchangeably. In various embodiments, the terms "power value P**2**" and "power P**2**" are used interchangeably.

It should be noted that each of slope **1** and slope **2** provides impedance at a point, in a plasma system, at which the variable is measured when the variable is voltage. It should further be noted that each of slope **1** and slope **2** provides an inverse of impedance at a point, in a plasma system, at which the variable is measured when the variable is current.

FIG. **2** is a diagram of an embodiment of a graph **104** to illustrate intra-chamber matching using a power control mode. In intra-chamber matching, the function of the variable is plotted along a y-axis and power provided to the plasma chamber **1** is plotted along an x-axis for the same plasma chamber **1** for two different conditions of the plasma chamber **1**. The two different conditions include a condition **1** and a condition **2**.

A solid line **105** is plotted when the plasma chamber **1** is in the condition **1**. The solid line **105** illustrates a relationship between the function of the variable and the power delivered to the plasma chamber **1** during the condition **1**. Moreover, a dashed line **107** is plotted when the plasma chamber **1** is in the condition **2**. The dashed line **107** is a relationship between the function of the variable and the power delivered to the plasma chamber **1** during the condition **2**.

In some embodiments, the condition **2** is a condition that occurs at a different time than a time of occurrence of the condition **1**. For example, the condition **2** occurs after corrosion of one or more elements of the plasma chamber **1** and the condition **1** occurs before the corrosion.

In several embodiments, the condition **2** is a condition that occurs after use of the plasma chamber **1** and the condition **1** is a condition that occurs before the use. The plasma chamber **1** is in the condition **1** before the use. For example, after the plasma chamber **1** is used to perform wet cleaning of a wafer, the plasma chamber **1** has a different condition, which is the condition **2**, than before the performance of the wet cleaning. As another example, after the plasma chamber **1** is used to etch a wafer, the plasma chamber **1** has a different condition, which is the condition **2**, than before the performance of the etching. As yet another example, after one or more gases, e.g., process gas, inert gas, a combination thereof, etc., are supplied within the plasma chamber **1**, the plasma chamber **1** has a different condition than before the supplying of the gases.

When the plasma chamber **1** is in the condition **1**, power is provided to the plasma chamber **1**, the power is plotted along the x-axis, the variable is measured at a point between the RF generator coupled to the plasma chamber **1** and a wafer in the plasma chamber **1**, and the function of the variable is plotted along the y-axis. The relationship illustrated using the solid line **105** is generated when the plasma chamber **1** is in the condition **1**.

Similarly, when the plasma chamber **1** is in the condition **2**, the relationship illustrated using the dashed line **107** is generated by providing power to the plasma chamber **1**, plotting the power along the x-axis, measuring the variable at a point between the RF generator coupled to the plasma chamber **1** and a wafer within the plasma chamber, calculating a function of the variable, and plotting the function versus the power.

Moreover, in a manner similar to that described above in case of the plasma chambers **1** and **2**, the power value P**2** is generated based on the variable function **1**. For example, a line is horizontally extended from a point **113**, corresponding to the variable function **1**, on the solid line **105** to intersect a point **115** on the dashed line **107**. The variable function **1** is achieved at both the points **113** and **115**. A line is vertically extended from the point **115** to a point P**2**, e.g., the power value P**2**, on the x-axis.

The power value P**2** is provided to the plasma chamber **1** when the plasma chamber **1** is in the condition **1** instead of providing the power value P**1** to achieve the variable function **1**.

It should be noted that in some embodiments, the condition **1** of the plasma chamber **1** results in a higher yield than that resulting during the condition **2** of the plasma chamber **1**. In various embodiments, the condition **2** of the plasma chamber **1** results in a higher yield than that resulting during the condition **1** of the plasma chamber **1**.

In various embodiments, instead of generating the power value P2 by extending a line horizontally from the point **113** and further by vertically extending a line from the point **115** towards the x-axis, the power value P1 is generated by extending a line horizontally from the point **115** to the solid line **105** to intersect the solid line **105** at the point **113** and vertically extending from the point **113** on the solid line **105** to the power value P1. The power value P1 is provided to the plasma chamber **1** during the condition **2** instead of providing the power value P2 to achieve the variable function **1**.

In several embodiments, regardless of whether the plasma chamber **1** is in the condition **1** or the condition **2**, a no-plasma test is performed using the plasma chamber **1** to obtain the relationships illustrated in the lines **105** and **107**. For example, pressure within the plasma chamber **1** is maintained at an amount below a threshold or above a threshold to avoid striking plasma within the plasma chamber **1**.

Furthermore, in some embodiments, instead of using the horizontal and/or vertical extensions, the slope **1** of the solid line **105** and the slope **2** of the dashed line **107** are calculated. The power value P2 is determined by multiplying the power value P1 with a ratio of slope **1** to slope **2**. The power value P2 is provided to the plasma chamber **1** during the condition **1** instead of providing the power value P1 during the condition **1**.

In various embodiments, instead of determining the power value P2 from the ratio of slopes **1** and **2**, the power value P1 is determined by multiplying the ratio of slope **2** to slope **1** to the power value P2, and the power value P1 is provided to the plasma chamber **1** during the condition **2**. The power value P1 is provided to the plasma chamber **1** instead of providing the power value P2 during the condition **2**.

FIG. **3** is a block diagram of an embodiment of a system **120** for generating one or more relationships between the function of the variable and power delivered to a plasma chamber **122** by using a probe **124** within an ESC **126**. The plasma chamber **122** is an example of the chamber **1**.

In some embodiments, one of the relationships, e.g., the relationship illustrated using the solid line **101** (FIG. **1**), the relationship illustrated using the solid line **105** (FIG. **2**), etc., is generated during the condition **1** of the plasma chamber **122** and another one of the relationships, e.g., the relationship illustrated using the dashed line **107** (FIG. **2**), etc., is generated during the condition **2** of the plasma chamber **122**.

A host system **128** is coupled to one or more RF generators, e.g., an x megahertz (MHz) RF generator, a y MHz RF generator, a z MHz RF generator, etc. The x MHz generator may be a 2 MHz RF generator, the y MHz RF generator may be a 27 MHz RF generator, and the z MHz RF generator may be a 60 MHz RF generator.

Examples of the host system **128** include a computer, a processor-based system, a workstation, a laptop, a desktop, a tablet, a cell phone, etc.

As used herein, a processor may be an application specific integrated circuit (ASIC), a programmable logic device (PLD), a microprocessor, a central processing unit (CPU), etc.

In some embodiments, instead of the 2 MHz RF generator, an RF generator of a different frequency, e.g., a 3 MHz RF generator, a 4 MHz RF generator, a 5 MHz RF generator, etc., may be used. Similarly, RF generators of different frequencies may be used instead of the y and z MHz RF generators.

In several embodiments, the x MHz RF generator may be a 27 MHz RF generator. In these embodiments, the y and z MHz RF generators are 2 and 60 MHz RF generators.

In a number of embodiments, the x MHz RF generator may be a 60 MHz RF generator. In these embodiments, the y and z MHz RF generators are 2 and 27 MHz RF generators.

When the plasma chamber **122** is in the condition **1**, the host system **128** sends power values and a frequency of operation to a digital signal processor (DSP) **130** of the x MHz RF generator. The DSP **130** sends the power values and the frequency to a driver and amplifier system (DAS) **132** of the x MHz RF generator.

The DAS **132** receives the power values and the frequency and generates an RF signal having the power values and the frequency. The RF signal is supplied via an RF cable **134** to a matchbox **136**, which is an impedance matching circuit.

In some embodiments, the DAS **132** amplifies an RF signal that is generated by a driver of the DAS to generate an amplified RF signal, which is supplied via the RF cable **134** to the matchbox **136**.

In various embodiments, when an RF signal is generated by the x MHz RF generator to generate the solid line **101** (FIG. **1**), the solid line **105** (FIG. **2**), the dashed line **103** (FIG. **1**), and/or the dashed line **107** (FIG. **2**), the y and z MHz RF generators do not generate RF signals. For example, the y and z MHz RF generators are turned off when the x MHz RF generator is used to generate an RF signal.

An impedance matching circuit includes electric circuit components, e.g., inductors, capacitors, etc. to match an impedance of a power source coupled to the impedance matching circuit with an impedance of a load coupled to the impedance matching circuit. For example, the matchbox **136** matches an impedance of a source, which includes one or more of the x, y, and z MHz RF generators that are operational, and an impedance of one or more of the RF cables **134**, **137**, and **138** with an impedance of an RF transmission line **140** and the plasma chamber **122**. The RF cables **134**, **137**, and **138** couple the matchbox **136** to the x, y, and z MHz RF generators. An impedance match between a power source and a load reduces chances of power being reflected from the load towards the power source.

The RF transmission line **140** is coupled to the matchbox **136** and to the plasma chamber **122**. The RF transmission line **140** includes an RF cable **142**, which is coupled to an RF tunnel **144**, and the RF tunnel **144** is coupled to an RF strap **148**. Within the RF tunnel **144** lays an insulator **150** and an RF rod **152**. The insulator **150** insulates the RF rod **152** from a sheath of the RF tunnel **144**. The RF rod **152** is coupled via a connector **146** to the RF strap **148**, which is sometimes also known as an RF spoon. The RF strap **148** is coupled to the lower electrode of the ESC **126**.

A wafer **154**, e.g., a semiconductor wafer, is supported on an upper surface **156** of the ESC **126**. Integrated circuits, e.g., application specific integrated circuits (ASICs), programmable logic devices (PLDs), etc. are developed on the wafer **154** and the integrated circuits are used in a variety of devices, e.g., cell phones, tablets, smart phones, computers, laptops, networking equipment, etc. An upper electrode **158** faces the lower electrode of the ESC **126**.

The plasma chamber **122** has walls W1, W2, W3, and W4 that enclose plasma that is generated within the plasma chamber **122**. It should be noted that in some embodiments, the plasma chamber **122** includes more than four walls. In several embodiments, a wall of the plasma chamber **122** may be perpendicular to an adjacent wall. In various embodiments, a wall of the plasma chamber **122** may form a non-perpendicular angle with an adjacent wall of the plasma chamber **122**.

The probe **124** is embedded within the ESC **126**. In several embodiments, instead of being embedded within the ESC

126, the probe **124** is coupled to the ESC **126**. The probe **124** may be located within the plasma chamber **122**.

Examples of the probe **124** include a current probe that measures current, a voltage probe that measures voltage, and a voltage and current probe that measures voltage and current. The probe **124** is coupled to the host system **128**. For example, the probe **124** is coupled to an analog-to-digital converter of the host system **128** and the analog-to-digital converter is coupled to a processor of the host system **128**.

In some embodiments, instead of the probe **124**, two probes are used. For example, a voltage probe that measures voltage and a current probe that measure current is used instead of the probe **124**.

An RF signal that is generated by the x MHz RF generator is communicated via the RF cable **134**, the matchbox **136**, the RF cable **142**, the RF rod **152**, the connector **146**, and the RF strap **148** to the lower electrode of the ESC **126**.

In some embodiments, the upper electrode **158** includes gas distribution apertures that are coupled to a central gas feed (not shown). The central gas feed receives one or more gases, e.g., process gases, inert gases, a combination thereof, etc., from a gas supply (not shown). Examples of process gases include an oxygen-containing gas, such as O_2. Other examples of a process gas include a fluorine-containing gas, e.g., tetrafluoromethane (CF_4), sulfur hexafluoride (SF_6), hexafluoroethane (C_2F_6), etc. The upper electrode **158** is grounded.

When the RF signal generated by the x MHz RF generator is provided to the plasma chamber **122**, a no-plasma test is performed. For example, an amount of pressure is maintained within the plasma chamber **122** that is in the condition **1** to avoid striking plasma within the plasma chamber **122**. As another example, a gas is not supplied or a limited amount of the gas is supplied to maintain pressure within the plasma chamber **122** below a threshold. During a no-plasma test, a minimal amount of plasma is generated in the plasma chamber **122**.

During the no-plasma test, the probe **124** measures a variable and sends the measurement to the host system **128**. The host system **128** receives the measurement of the variable and the analog-to-digital converter of the host system **128** converts the measurement from an analog form to a digital form. In some embodiments, the probe **124** converts the measurement from an analog to a digital form before sending the measurement to the host system **128**.

The processor of the host system **128** generates the function of the variable based on the measurement of the variable. For example, the processor of the host system **128** calculates a square of the variable. It should be noted that a sensor **160**, e.g., a voltage and current sensor, a power sensor, etc., which is coupled to the RF cable **134**, measures supplied power, which is power supplied by the x MHz RF generator, or measures, delivered power, which is a difference between the supplied power and power that is reflected via the RF cable **134** from the plasma chamber **122** towards the x MHz RF generator. The measurement of the provided power is sent by the sensor **160** via the DSP **130** to the processor of the host system **128**. Continuing with the example, the processor determines a relationship, e.g., the relationship illustrated in the solid line **101** (FIG. **1**), the relationship illustrated in the solid line **105** (FIG. **2**), etc., between the function of the variable and the provided power over a period of time.

In some embodiments, instead of the sensor **160** measuring both the supplied and reflected powers, the sensor **160** measures reflected power and the supplied power is a power value sent by the host system **128** to the DSP **130**.

Also, when a condition of the plasma chamber **122** changes after the relationship is determined, a no-plasma test is performed. For example, an amount of pressure is maintained within the plasma chamber **122** that is in the condition **2** to avoid striking plasma within the plasma chamber **122**. The probe **124** measures the variable of the plasma and the sensor **160** measures the supplied and reflected powers.

After the condition changes, the processor of the host system **128** receives the measurement of the variable from the probe **124** and receives the measurements of the supplied and reflected powers via the DSP **130**, calculates the function of the variable from the measurement of the variable, determines delivered power from the supplied and reflected powers, and determines a relationship, e.g., the relationship illustrated in the dashed line **107** (FIG. **2**), etc., between the function of the variable and the delivered power over a period of time.

In some embodiments, instead of using the delivered power to determine the relationship during the condition **2**, the supplied power is used. For example, a relationship between the supplied power and the function of the variable is determined.

During or before subsequent processing of the wafer **154**, the processor of the host system **128** performs intra-chamber matching for the plasma chamber **122** in a manner described above with reference to FIG. **2**. For example, the processor calculates the slope **1** and the slope **2** (FIG. **2**), calculates a ratio of the slope **2** and the slope **1**, multiplies the power value **P1** with the ratio to compute the power value P**2**. As another example, instead of determining the ratio of the slope **2** to slope **1** (FIG. **2**), the processor calculates a ratio of the slope **1** to the slope **2** (FIG. **2**) and multiplies the power value P**2** with the ratio to compute the power value P**1**. As yet another example, to achieve the variable function **1** during the condition **1**, the processor extends a line horizontally from the point **113** to intersect the dashed line **107** at the point **115** (FIG. **2**). Continuing with the example, the processor extends a vertical line from the intersected point **115** to intersect the x-axis (FIG. **2**) at the power value P**2** to determine the power value **P2** for the condition **1**. As another example, to achieve the variable function **1** during the condition **2**, the processor extends a line horizontally from the point **115** to intersect the solid line **105** at the point **113** (FIG. **2**). The processor extends a line vertically from the intersected point **113** on the solid line **105** to intersect a point, which is the power value P**1**, on the x-axis to determine the power value P**1** for the condition **2**. The subsequent processing of the wafer **154** occurs after obtaining the graph **102** and/or the graph **104** (FIGS. **1** and **2**).

Examples of processing the wafer **154** includes cleaning the wafer, depositing materials on the wafer **154**, etching the wafer **154**, sputtering the wafer **154**, applying plasma to the wafer **154**, etc.

In some embodiments, during the subsequent processing of the wafer **154**, a power value, e.g., the power value P**1**, the power value P**2**, etc., to be provided to the plasma chamber **122** that is in a condition, e.g., the condition **1**, the condition **2**, etc., is identified, e.g., read, etc., from a storage device of the host system **128**. The storage device is further described below. When an RF signal having the power value is supplied and the process gas is supplied to the plasma chamber **122** during the subsequent processing, plasma is stricken within the plasma chamber **122**. The plasma is used to process the wafer **154**.

In various embodiments, a processing condition is achieved during the subsequent processing of the wafer **154**. For example, during the subsequent processing using the plasma chamber **122** in the condition **2**, the power value P**1** and the variable function **1** are achieved. As another example, during the subsequent processing using the plasma chamber **122** in the condition **1**, the power value P**2** and the variable function **1** are achieved.

In some embodiments in which the power values plotted along the x-axis are delivered power values, during subsequent processing of the wafer **154**, when the plasma chamber **122** is in the condition **1** and the power value P**2** associated with the condition **2** is to be delivered to the plasma chamber **122**, the processor of the host system **128** determines a supply power value to achieve the delivered power value P**2** and instead of sending a supply power value to achieve the delivered power value P**1**, sends the supply power value to achieve delivered power P**2** during the condition **1** of the plasma chamber **122**. For example, the processor supplies a power value to the DSP **130**, which sends the power value to the DAS **132**. The DAS **132** generates an RF signal based on the power value and supplies the RF signal to the plasma chamber **122**. When the RF signal is supplied to the plasma chamber **122**, the sensor **160** measures reflected power and sends the measurement to the processor of the host system **128**. The processor of the host system **128** calculates the delivered power from the measurement of the reflected power and the supplied power of the RF signal and determines whether the delivered power is equal to the power value P**2**. Upon determining that the delivered power value is equal to P**2**, the processor of the host system **128** continues to send a supply power value to achieve the delivered power value P**2** to the DSP **130** to continue to supply the RF signal corresponding to the delivered power P**2**. On the other hand, the operations of changing the supplied power value, measuring the supplied and reflected power, and calculating the delivered power are repeated until the delivered power matches the power value P**2**.

Similarly, in various embodiments in which the power values plotted along the x-axis are delivered power values, during subsequent processing of the wafer **154**, when the plasma chamber **122** is in the condition **2** and the power value P**1** associated with the condition **1** is to be delivered to the plasma chamber **122**, the processor of the host system **128** determines a supply power value to achieve the delivered power value P**1** and instead of sending a supply power value to achieve the delivered power value P**2**, sends the supply power value to achieve the delivered power value P**1** during the condition **2** of the plasma chamber **122**.

In embodiments in which the power values plotted along the x-axis are supply power values, during subsequent processing of the wafer **154**, when the plasma chamber **122** is in the condition **1** and the power value P**2** associated with the condition **2** is to be supplied to the plasma chamber **122**, the processor of the host system **128** sends the power value P**2** during the condition **1** of the plasma chamber **122** instead of sending the power value P**1** during the condition **1** to achieve the variable function **1** and the x MHz RF generator supplies an RF signal having the power value P**2** instead of supplying an RF signal having the power value P**1**.

Similarly, in a number of embodiments in which power values plotted along the x-axis are supply power values, during subsequent processing of the wafer **154**, when the plasma chamber **122** is in the condition **2** and the power value P**1** associated with the condition **1** is to be supplied to the plasma chamber **122**, the processor of the host system **128** sends the power value P**1** during the condition **2** of the plasma chamber **122** instead of sending the power value P**2** during the condition **2** to achieve the variable function **1** and the x MHz RF generator supplies an RF signal having the power value P**1** instead of supplying an RF signal having the power value P**2**.

In several embodiments, instead of using the probe **124** in conjunction with the host system **128**, a network analyzer or an impedance scanner is used instead of the probe **124**. For example, the network analyzer includes an RF probe that is coupled to a network analyzer, which is further coupled to the host system **128**. The RF probe may be a small microwave antenna. The network analyzer supplies electrical signals to the RF probe. Upon receiving the electrical signals, the RF probe launches microwave signals into the plasma chamber **122**. The microwave signals interact with the plasma within the plasma chamber **122** and are detected by the RF probe. The RF probe converts the detected microwave signals into electrical signals. The network analyzer determines a reflection coefficient from the electrical signals and sends the reflection coefficient to the host system **128**. The processor of the host system **128** keeps track of a change in the reflection coefficient over time and generates a graph, e.g., the graph **102** (FIG. **1**), the graph **104** (FIG. **2**), etc., to determine relationships between the reflection coefficient and power provided to the lower electrode of the ESC **126**. The relationships are then used by the processor of the host system **128** to determine power to provide to the lower electrode to achieve a condition, e.g., the condition **1**, the condition **2**, etc., or to perform chamber-to-chamber matching.

In several embodiments, when the network analyzer or the impedance scanner is used, a no-plasma test is performed within the plasma chamber **122**.

FIG. **4**A is a block diagram of an embodiment of a plasma system **172** for generating one or more relationships between the function of the variable and power delivered to a plasma chamber **123** by using the probe **124** within an RF tunnel **176**. The plasma system **172** operates in a similar manner as that of the plasma system **120** (FIG. **3**) except that the plasma chamber **123** excludes the probe **124** within the ESC **126**. Instead, the plasma system **172** includes the probe **124** within an insulator of the RF tunnel **176**. The probe **124** is coupled to an output of the RF rod **152**.

The output of the RF rod **152** is coupled to an input of the RF strap **148** via the connector **146**. An input of the RF rod **152** is coupled to an output of the RF cable **142**. An input of the RF cable **142** is coupled to the matchbox **136**. An output of the RF strap **148** is coupled to a lower electrode of an ESC **127** of a plasma chamber **123**. The ESC **127** is similar in structure and function to the ESC **126** (FIG. **3**) except that the ESC **127** excludes the probe **124** (FIG. **3**).

In some embodiments, the probe **124** is coupled to the RF rod **152** and is located outside the RF tunnel **176**.

The RF cable **142**, the RF rod **152**, the RF tunnel **176**, the connector **146**, and the RF strap **148** are parts of an RF transmission line **178** that couple the matchbox **136** to the lower electrode of the ESC **127**.

The probe **124** measures the variable when the x MHz RF generator supplies power to the plasma chamber **123**. The power is supplied to the plasma chamber **123** via the RF cable **134**, the matchbox **136**, and the RF transmission line **178**.

In some embodiments, the variable is measured from the plasma chamber **123** when the process gas is supplied to the plasma chamber **123** and an RF signal is provided to the plasma chamber **123** to strike plasma within the plasma chamber **123**.

In several embodiments, the variable is measured during a no-plasma test. For example, the variable is measured from the plasma chamber **123** when an RF signal is provided to the plasma chamber **123**, a gas is supplied to the plasma chamber, and an amount of pressure is maintained below a threshold or above a threshold to avoid striking plasma within the plasma chamber **123** or to strike a minimal amount of plasma within the plasma chamber **123**.

The measurement of the variable is sent by the probe **124** to the host system **128**. Upon receiving the measurement of the variable, the analog-to-digital converter of the host system **128** converts the measurement from an analog form to a digital form and sends the digital measurement to the processor of the host system **128**. The processor of the host system **128** applies a computer-generated model of one or more portions of the RF transmission line **178** and/or of the ESC **127** to the measurement in the digital form to determine the variable at the ESC **127**. The computer-generated model is described below.

In some embodiments, instead of performing the conversion from the analog to the digital format within the host system **128**, the probe **124** converts the analog measurement of the variable to the digital format and sends the digital measurement to the processor of the host system **128**.

FIG. **4**B is a block diagram of an embodiment of a host system **180** for using a computer-generated model to determine a value of a variable at an ESC model **182**. The host system **180** includes a processor **184** and a storage device **186**, e.g., a random access memory (RAM), a read-only memory (ROM), or a combination thereof. In some embodiments, the storage device **186** is a hard disk, a flash memory, a disk array, etc. The host system **180** is an example of the host system **128** (FIG. **3**). The storage device **186** is coupled to the processor **184** and stores a cable model **188**, a tunnel model **190**, a strap model **192**, and the ESC model **182**.

It should be noted that the cable model **188** is a computer-generated model of the RF cable **142** (FIG. **4**A), the tunnel model **190** is a computer-generated model of the RF tunnel **176** (FIG. **4**A), the strap model **192** is a computer-generated model of the RF strap **148** (FIG. **4**A), and the ESC model **182** is a computer-generated model of the ESC **127** (FIG. **4**A). For example, the tunnel model **190** has similar characteristics, e.g., capacitances, inductances, complex power, complex voltage and currents, etc., as that of the RF rod **152**. As another example, the tunnel model **190** has the same capacitance, inductance, resistance, or a combination thereof as that of the RF rod **152**. As yet another example, the strap model **192** has the same capacitance, inductance, resistance, or a combination thereof as that of the RF strap **148** (FIG. **4**A). As another example, the ESC model **182** has the same capacitance, inductance, resistance, or a combination thereof as that of the ESC **127** (FIG. **4**A).

The processor **184** receives the measurement of the variable from the probe **124** (FIG. **4**A). The processor **184** determines a value of the variable at an output of the ESC model **182** based on the measurement of the variable received from the probe **124** and the characteristics of the strap model **192** and the ESC model **182**. For example, the processor **184** receives a magnitude of the current at the output of the RF rod **152** (FIG. **4**A), receives a magnitude of the voltage at the output of the RF rod **152**, and receives a phase between the voltage and current, and determines a directed sum of the current, the voltage, and the phase and currents and voltages generated by the capacitances, inductances, and/or resistances of the strap model **192** and the ESC model **182** to determine voltage and current at the output of the ESC model **182**. The currents and voltage generated by the capacitances, inductances, and/or resistances of the strap model **192** and the ESC model **182** include magnitudes of the voltages, magnitudes of the currents, and phases of the currents. In some embodiments, a resistance excludes a phase and is defined in terms of a current magnitude and a voltage magnitude.

The processor **184** uses the value of the variable at the output of the ESC model **182** instead of the measurement of the variable from the probe **124** to calculate the function of the variable to further determine relationships of the function of the variable with power that is provided to the plasma chamber **122** (FIG. **4**A). Based on the relationships, the processor **184** calculates the power value P**1** or the power value P**2**.

In various embodiments, the probe **124** is connected to an input of the RF rod **152** instead of to the output of the RF rod **152**. In these embodiments, the processor **184** determines a value of the variable at an output of the ESC model **182** based on the measurement of the variable received from the probe **124** and the characteristics of the tunnel model **190**, the strap model **192** and the ESC model **182**.

In various embodiments, the probe **124** is coupled to any point between the x MHz RF generator and the wafer **154** (FIG. **4**A). For example, the probe **124** is coupled to the RF cable **134** (FIG. **4**A). In these embodiments, a computer-generated model of elements of the plasma system **172** (FIG. **4**A) between the point and the wafer **154** is generated and variable at a computer-generated model of the ESC **127** is determined based on the variable measured with the probe **124** and impedances of elements between the point and the wafer **154**. For example, when the probe **124** is coupled to a point on the RF cable **134**, a computer-generated model of elements of the plasma system **172** between a portion of the RF cable **134** from the point to the matchbox **136**, a computer model of the matchbox **136**, a computer model of the RF cable **142**, a computer model of the RF rod **152**, a computer model of the RF strap **148**, and a computer model of the ESC **127** are generated. In this example, a variable at the ESC model **182** is determined based on the variable measured at the point and impedances of a computer-generated model of the portion of the RF cable **134** (FIG. **4**A), a computer-generated model of the matchbox **136**, the cable model **188**, the tunnel model **190**, the strap model **192**, and the ESC model **182**. As another example, when the probe **124** is coupled to an output of the x MHz RF generator, a computer model of the RF cable **134**, a computer model of the matchbox **136**, a computer model of the RF transmission line **178**, and a computer model of the ESC **127** are generated. The output of the x MHz RF generator is coupled to an input of the RF cable **134** (FIG. **4**A). In this example, a variable at the output of the x MHz RF generator is measured and the variable at the wafer **154** is determined based on the measured variable and impedances of elements, e.g., resistors, capacitors, inductors, etc., of the RF cable **134**, the matchbox **136**, the RF transmission line **178**, and the ESC **127**.

In various embodiments, the ESC model **182** is not used to determine a variable at the ESC **127** (FIG. **4**A). For example, when the probe **124** is coupled to a point on the RF cable **134**, a computer model of elements of the plasma system **172** between a portion of the RF cable **134** from the point to the matchbox **136**, a computer model of the matchbox **136**, a computer model of the RF cable **142**, a computer model of the RF rod **152**, and a computer model of the RF strap **148** are generated. In this example, a variable at the ESC model **182** is determined based on the variable measured at the point and impedances of a computer-generated model of the portion of the RF cable **134**, a computer-generated model of the matchbox **136**, the cable model **188**, the tunnel model **190**, and the strap model **192**.

FIG. **5** is a block diagram of an embodiment of a plasma system **200** for illustrating inter-chamber matching between the plasma chamber **122** (FIG. **3**) and a plasma chamber **202**, which is an example of the chamber **2**. The system **200** is similar to the system **120** (FIG. **3**) except that the system **200** includes a plasma chamber **202** instead of the plasma chamber **122**. For example, the plasma chamber **202** has a different identification code than the plasma chamber **122** and both the plasma chambers **202** and **122** have the same structure and/or function. As another example, one or more elements of the plasma chamber **122** are replaced with one or more elements of the plasma chamber **202**. As yet another example, the ESC **204** replaces the ESC **126** (Figure **3**) of the plasma chamber **122**. In some embodiments, the one or more elements of the plasma chamber **202** that replace the one or more elements of the plasma chamber **122** have the same structure and/or function as that of the one or more elements of the plasma chamber **122**. For example, the ESC **204** has the same dimensions as that of the ESC **126**. As another example, the ESC **204** includes the same elements, e.g., a heater, a thermal insulator, a ceramic support, etc. as that of the ESC **126**. As yet another example, the ESC **204** has the same characteristics, e.g., inductance, capacitance, resistance, a combination thereof, etc., as that of the ESC **126**. As another example, both the ESC **204** and **126** are provided with power by an RF generator. As another example, both the plasma chambers **202** and **122** are of the same type. To illustrate, a TCP chamber is of a different type than an ICP chamber and both the TCP and the ICP chambers are of a different types than an ECR plasma chamber.

In some embodiments, the plasma chamber **122** is an example of the plasma chamber **1** and the plasma chamber **202** is an example of the plasma chamber **2**.

In some embodiments, the plasma chamber **122** is decoupled from the RF transmission line **140** to couple the plasma chamber **202** to the RF transmission line **140**. The wafer **154** is placed on an upper surface **206** of the ESC **204**. The upper surface **206** faces the upper electrode **158**.

In some embodiments, the relationship illustrated using the dashed line **103** (FIG. **1**) is generated using the plasma chamber **202**.

The probe **124** is embedded within the ESC **204** in a manner similar to that of embedding the probe **124** within the ESC **126**. In several embodiments, instead of embedding the probe **124** within the ESC **204**, the probe **124** is coupled to the ESC **204** and is located outside the ESC **204**.

During performance of a no-plasma test using the plasma chamber **202**, the host system **128** determines an amount of power within an RF signal and a frequency of the RF signal to supply to the plasma chamber **202**. The amount of power and the frequency are sent as inputs via the DSP **130** to the DAS **132**. The DAS **132** generates an RF signal having the amount of power and the frequency. The RF signal is supplied by the x MHz RF generator via the RF cable **134**, the matchbox **136**, and the RF transmission line **140** to the lower electrode of the ESC **204**. When the process gas is supplied to the plasma chamber **202** and power is supplied to the lower electrode of the ESC **204** via the RF signal, plasma is generated within the plasma chamber **202**.

As described above, in several embodiments in which a no-plasma test is performed, when power is supplied to the lower electrode of the ESC **204** via the RF signal and an amount of pressure less than a threshold or greater than a threshold is maintained within the plasma chamber **202**, a minimal amount of plasma is struck within the plasma chamber.

During the no-plasma test, the probe **124** measures the variable associated with plasma of the plasma chamber **202** and sends the measurement to the host system **128**. The processor of the host system **128** calculates a function of the variable from the measurement of the variable. The processor of the host system **128** determines a relationship, such as, for example, the relationship illustrated using the dashed line **103** of the graph **102** (FIG. **1**), from the function of the variable and power supplied by the x MHz RF generator to the plasma chamber **202**.

In some embodiments, instead of determining the relationship between the function of the variable and the supplied power during the no-plasma test, the processor of the host system **128** determines a relationship between the function of the variable and power delivered to the plasma chamber **202** during the no-plasma test. For example, the sensor **160** measures power reflected from the plasma chamber **202** towards the x MHz RF generator. The sensor **160** sends the reflected power measurement to the processor of the host system **128** via the DSP **130**. The processor of the host system **128** calculates a difference between the supplied power and the reflected power to determine delivered power, and further determines the relationship, illustrated in the dashed line **103** of the graph **102**, between the function of the variable and the delivered power.

When the plasma chamber **122** (FIG. **3**) is the golden chamber, the processor of the host system **128** horizontally extends a line from the point **111** on the dashed line **103** (FIG. **1**) corresponding to the variable function **1** to intersect the solid line **101** at the point **109**. The processor of the host system **128** vertically extends a line from the intersected point **109** towards the x-axis to intersect the x-axis at the power value P1.

During subsequent processing of the wafer **154**, instead of sending the power value P2 to the DAS **132** via the DSP **130** to achieve the variable function **1**, the processor of the host system **128** identifies and sends the power value P1 to the DAS **132** via the DSP **130** to achieve the variable function **1**. For example, the processor of the host system **128** identifies, e.g., reads, etc., from the storage device **186** (FIG. **4**B) the power value P1 that is associated with the power value P2. The power values P1 and P2 are associated with each other as achieving the variable function **1**. Upon receiving the power value P1, the DAS **132** generates an RF signal having the power value P1 and sends the RF signal via the RF cable **134**, the matchbox **136**, and the RF transmission line **140** to the lower electrode of the ESC **204**. The power value P1 that is read from the storage device **186** and that is used to achieve the variable function **1**, and the variable function **1** are examples of a processing condition.

In some embodiments, the power value P2 that is read from the storage device **186** and that is used to achieve the variable function **1**, and the variable function **1** are examples of a processing condition.

When the RF signal is provided to the lower electrode of the ESC **204** and the process gas is supplied to the plasma chamber **202**, plasma is stricken within the plasma chamber **202** to perform processing, e.g., etching, cleaning, depositing, etc., on the wafer **154**. Also, when the RF signal having the power value P1 instead of the power value P2 is provided to the lower electrode of the ESC **204**, power provided to the lower electrode is adjusted from the value P2 to the value P1 to achieve the variable function **1**.

In some embodiments, the processor of the host system **128** determines the slope **2** from the relationship illustrated using the dashed line **103** of the graph **102** (FIG. **1**). The processor of the host system **128** also determines the slope **1** from the relationship illustrated using the solid line **101** (FIG. **1**). When the variable is voltage, the processor of the host system **128** calculates a ratio of slope **1** to slope **2** and multiplies the power value P2 with the ratio of slope **1** to slope **2** to achieve the power value P1 and to achieve the variable function **1**.

During subsequent processing of the wafer **154**, instead of controlling the x MHz RF generator to supply the power value P2 to achieve the variable function **1**, the processor of the host system **128** controls the x MHz RF generator to supply the power value P1 to achieve the variable function **1**. Upon receiving an indication from the processor of the host system **128** via the DSP **130** to generate an RF signal having the power value P1, the DAS **132** generates an RF signal having the power value P1 and supplies the RF signal via the RF cable **134**, the matchbox **136**, and the RF transmission line **140** to the lower electrode of the ESC **204**.

In various embodiments in which the relationships illustrated in the graph **102** (FIG. **1**) are relationships between the function of the variable and delivered power, during subsequent processing of the wafer **154**, the processor of the host system **128** determines a supply power value to achieve the delivered power value of P1 and to achieve the variable function **1**. The processor provides the supply power value to the DAS **132** via the DSP **130**. The DAS **132** generates an RF signal having the supply power value corresponding to the delivered power value P1 to achieve the variable function **1**. The RF signal is supplied by the x MHz RF generator via the RF cable **134**, the matchbox **136**, and the RF transmission line **140** to the lower electrode of the plasma chamber **202**.

In some embodiments, instead of using the probe **124** within the ESC **204**, the probe **124** is embedded within the RF tunnel **144** and/or is coupled to the RF rod **152** to measure variable at the RF rod **152**. A computer-generated model of the RF rod **152**, the RF strap **148**, and the ESC **204** is used to determine a variable at the ESC **204**. The variable at the ESC **204** is determined based on the variable measured using the probe **124** that is embedded within the RF tunnel **144** and impedance of elements of the RF rod **152**, the RF strap **148**, and the ESC **204**. In several embodiments, instead of using a computer-generated model of the ESC **204**, the variable at the ESC **204** is determined based on a computer-generated model of the RF rod **152** and the RF strap **148** and based on the variable measured using the probe **124** that is embedded within the RF tunnel **144**.

In some embodiments, the probe **124** is coupled to a point between the x MHz RF generator and the wafer **154** and a computer-generated model of elements between the point and the plasma chamber **204** is used to determine a variable at the ESC **204**. For example, the probe **124** is coupled to the RF cable **134** to determine the variable at the RF cable **134**. Moreover, a computer-generated model of the matchbox **136**, the RF transmission line **140**, and the ESC **204** is used to determine the variable at the ESC **204**. As another example, the probe **124** is coupled to the RF cable **134** to determine the variable at the RF cable **134**. Moreover, a computer-generated model of the matchbox **136** and the RF transmission line **140** is used to determine the variable at the ESC **204**.

It should be noted that in several embodiments, when the x MHz RF generator of the system **200** is used to supply power to the plasma chamber **202** to determine the relationship illustrated using the graph **102** or **104** (FIGS. **1** and **2**), the y and z MHz RF generators are turned off. Similarly, when the y MHz RF generator of the system **200** is used to supply power to the plasma chamber **202** to determine the relationship illustrated using the graph **102** or **104**, the x and z MHz RF generators are turned off. Also, when the z MHz RF generator of the system **200** is used to supply power to the plasma chamber **202** to determine the relationship illustrated using the graph **102** or **104**, the x and y MHz RF generators are turned off.

FIG. **6** is a diagram of an embodiment of a graph **210** used to illustrate a relationship between voltage and pressure during a no-plasma test. The graph **210** plots voltage along a y-axis and plots pressure along an x-axis. When the pressure is below a threshold th**1**, a minimal amount of plasma is generated within a plasma chamber. In some embodiments, the pressure lower than the threshold th**1** is achieved by not supplying the process gas or by supplying the process gas at an ultra low flow rate, e.g., less than 0.2 standard cubic centimeter per minute (sccm). Similarly, when the pressure is above a threshold th**2**, plasma is not generated or a minimal amount of plasma is generated within a plasma chamber. In some embodiments, the pressure above the threshold th**2** is achieved by supplying a gas at an ultra high pressure, e.g., greater than or equal to 7 Torr, at a maximum achievable flow rate, etc. When plasma is not generated or a minimal amount of plasma is generated within a plasma chamber, the plasma chamber is used to perform the no-plasma test.

In some embodiments, the processor of the host system **128** controls a gas supply valve (not shown) that facilitates supply of a gas from a gas reservoir (not shown) to the gas inlets of the upper electrode **158** (FIGS. **3**, **4**A, and **5**). For example, the processor controls a driver, e.g., a transistor, etc., that supplies a current to open or close the valve by an amount to control the supply of the gas. The control of the supply also allows the processor of the host system **128** to control the pressure within a plasma chamber in which the gas is supplied.

FIG. **7** shows an embodiment of a recipe **212** for performing chamber-to-chamber matching. In some embodiments, the recipe **212** is part of a database that is stored within the storage device **186** (FIG. **4**B) of the host system **128** (FIGS. **3**, **4**A, and **5**). For example, the recipe **212** may be stored in the form of a file within the storage device **186**.

The recipe **212** includes pressure of a gas in a plasma chamber, power of an RF signal that is provided to a lower electrode of a plasma chamber, temperature maintained within the plasma chamber, frequency of the RF signal, and gap between the lower electrode and an upper electrode of the plasma chamber.

In some embodiments, the processor of the host system **128** (FIGS. **3**, **4**A, and **5**) sends a frequency of an RF signal to an RF generator. A DSP of the RF generator receives the frequency and sends the frequency to a DAS of the RF generator. The DAS generates an RF signal having the frequency and supplies the RF signal to a plasma chamber.

In various embodiments, the upper electrode is located within an upper structure (not shown) that is may be raised up or down using a motor-driven screw mechanism (not shown). The processor of the host system **128** may control the motor-driven screw mechanism via a driver to move the upper structure up or down to change the gap between the upper and lower electrodes

In several embodiments, a heater is included within an ESC and the heater is controlled by the processor of the host system **128** via a driver to change temperature within a plasma chamber.

In a number of embodiments, a heat transfer mechanism, e.g., a duct, etc., is provided within a plasma chamber and a flow of a cooling liquid is controlled by the processor of the host system **128** via a valve and a driver to change temperature within the plasma chamber.

The recipe **212** is applied by the processor of the host system **128** to control pressure within a plasma chamber, power of an RF signal provided to a lower electrode of the plasma chamber, temperature within the plasma chamber, frequency of the RF signal, and gap between the lower electrode and an upper electrode within the plasma chamber.

In various embodiments, the power shown in the recipe **212** is delivered power or supplied power.

As indicated in the recipe **212**, the same recipe **212** is applied to the chamber **1**, the chamber **2**, and a chamber **3** (not shown). For example, the processor of the host system **128** controls pressure within the chambers **1**, **2**, and **3**, power of RF signals provided to the chambers **1**, **2**, and **3**, temperature within the chambers **1**, **2**, and **3**, frequency of the RF signals, and gaps between lower and upper electrodes of the chambers **1**, **2**, and **3** to apply the same recipe **212** to the chambers **1**, **2**, and **3**. As another example, the recipe **212** is applied to generate the relationship illustrated in the solid line **101** and the relationship illustrated in the dashed line **103** (FIG. **1**).

In some embodiments, during application of the recipe **212** to the chamber **1**, **2**, or **3**, pressure within the chamber, temperature within the chamber, frequency of an RF signal provided to the chamber, and gap between a lower electrode and an upper electrode of the chamber are maintained as constant, and power of the RF signal is varied from 5 megawatts to 10 megawatts to 15 megawatts to 20 megawatts.

In some embodiments, an amount of pressure of the recipe **212** maintained within the chambers **1**, **2**, and **3** is less than the threshold th**1** or greater than the threshold th**2**.

It should be noted that the values of pressure, power, temperature, frequency, and gap are examples and should not be construed as limiting. For example, instead of 0.1 Torr pressure, a pressure ranging from 0 to 0.2 Torr is applied. As another example, instead of 5, 10, 15, and 20 megawatts, power is varied from 2 megawatts to 6 megawatts to 10 megawatts to 14 megawatts. As yet another example, any amount of power ranging from 1 to 50 megawatts is applied. As another example, instead of 28 MHz frequency, a frequency of 27 MHz is applied. As yet another example, when a 2 MHz RF generator is used, a frequency of 2 or 3 MHz may be applied. As another example, when a 60 MHz RF generator is used, a frequency between 55 MHz to 65 MHz is applied. As another example, instead of 2 centimeter, a gap between 1 and 3 centimeters is maintained.

FIG. **8** shows an embodiment of a recipe **212** for performing intra-chamber matching. As indicated in the recipe **212**, the same recipe **212** is applied to the chamber **1** during the condition **1**, the condition **2**, and a condition **3** of the chamber **1**. For example, the processor of the host system **128** controls pressure within the chamber **1** during the conditions **1** and **2**, power of RF signals provided to the chamber **1** during the conditions **1** and **2**, temperature within the chamber **1** during the conditions **1** and **2**, frequency of the RF signals, and gaps between lower and upper electrodes of the chamber **1** during the conditions **1** and **2** to apply the same recipe **212** to the chamber **1** during the conditions **1**, **2**, and **3** of the chamber **1**. As another example, the recipe **212** is applied to generate the relationship illustrated in the solid line **105** and the relationship illustrated in the dashed line **107** (FIG. **3**).

In some embodiments, during application of the recipe **212** to the chamber **1** during the conditions **1**, **2**, and **3**, pressure within the chamber **1**, temperature within the chamber **1**, frequency of an RF signal provided to the chamber **1**, and gap between a lower electrode and an upper electrode of the chamber **1** are maintained as constant, and power of the RF signal is varied from 5 megawatts to 10 megawatts to 15 megawatts to 20 megawatts.

In various embodiments, the condition **3** occurs after occurrence of the condition **2**. In various embodiments, after processing, e.g., etching, depositing, cleaning, supply of a gas, etc., on the wafer **154** (FIGS. **3**, **4**A, and **5**) is performed within a plasma chamber during the condition **2**, the plasma chamber achieves the condition **3**.

FIG. **9**A is a diagram of an embodiment of a graph **220** used to illustrate a difference in relationships between three plasma chambers. As shown in the graph **220**, there are three lines **222**, **224**, and **226**. Each line **222**, **224**, and **226** shows a relationship between a square of current measured at an ESC of the plasma chamber and forward power, e.g., supplied power. The line **222** illustrates a relationship for the plasma chamber **1**, the line **224** illustrates a relationship for the plasma chamber **2**, and the line **226** illustrates a relationship for a golden chamber, which may be the chamber **3**. As noted, slope of the line **222** is different than slope of the line **224**. Also, slope of the line **224** is different than slopes of the lines **222** and **226**.

The golden chamber provides a higher yield than the chambers **1** and **2**. Relationships illustrated by the lines **222** and **224** are controlled to achieve the relationship illustrated by the line **226**.

FIG. **9**B an embodiment of a graph **230** used to illustrate a similarity in relationships between three plasma chambers after applying several embodiments described in the present disclosure. As shown in the graph **230**, there are three lines **232**, **234**, and **236**. Each line **232**, **234**, and **236** shows a relationship between a square of current measured at an ESC of the plasma chamber and forward power, e.g., supplied power. The line **232** illustrates a relationship for the plasma chamber **1**, the line **234** illustrates a relationship for the plasma chamber **2**, and the line **236** illustrates a relationship for a golden chamber, which may be the chamber **3**.

The line **236** is the same as the line **226** (FIG. **9**A) except that the line **236** is dashed.

As shown, slope of the lines **232**, **234**, and **236** is the same or substantially the same.

It is further noted that although the above-described operations are described with reference to a parallel plate plasma chamber, e.g., a capacitively coupled plasma chamber, etc., in some embodiments, the above-described operations apply to other types of plasma chambers, e.g., a plasma chamber including an ICP reactor, a TCP reactor, conductor tools, dielectric tools, a plasma chamber including an ECR reactor, etc. For example, the x MHz RF generator and the y MHz RF generator are coupled to an inductor within the ICP plasma chamber.

It is also noted that although the operations above are described as being performed by the processor of the host system **128** (FIGS. **3**, **4**A, and **5**), in some embodiments, the operations may be performed by one or more processors of the host system **128** or by multiple processors of multiple host systems.

It should be noted that although the above-described embodiments relate to providing an RF signal to the lower electrode of an ESC, and grounding the upper electrode **158** (FIGS. **3**, **4**A, and **5**), in several embodiments, the RF signal is provided to the upper electrode **158** while the lower electrode is grounded.

It is also noted that although the above-described embodiments are described using an ESC, another type of chuck, e.g., a magnetic chuck, etc., may be used.

It is further noted that in several embodiments, the operations described above as performed by the processor of the host system **128** may be performed by the DSP **130** (FIGS. **3**, **4**A, and **5**).

Embodiments described herein may be practiced with various computer system configurations including hand-held hardware units, microprocessor systems, microprocessor-based or programmable consumer electronics, minicomputers, mainframe computers and the like. The embodiments can also be practiced in distributed computing environments where tasks are performed by remote processing hardware units that are linked through a network.

With the above embodiments in mind, it should be understood that the embodiments can employ various computer-implemented operations involving data stored in computer systems. These operations are those requiring physical manipulation of physical quantities. Any of the operations described herein that form part of the embodiments are useful machine operations. The embodiments also relates to a hardware unit or an apparatus for performing these operations. The apparatus may be specially constructed for a special purpose computer. When defined as a special purpose computer, the computer can also perform other processing, program execution or routines that are not part of the special purpose, while still being capable of operating for the special purpose. In some embodiments, the operations may be processed by a general purpose computer selectively activated or configured by one or more computer programs stored in the computer memory, cache, or obtained over a network. When data is obtained over a network, the data may be processed by other computers on the network, e.g., a cloud of computing resources.

One or more embodiments can also be fabricated as computer-readable code on a non-transitory computer-readable medium. The non-transitory computer-readable medium is any data storage hardware unit that can store data, which can be thereafter be read by a computer system. Examples of the non-transitory computer-readable medium include hard drives, network attached storage (NAS), ROM, RAM, compact disc-ROMs (CD-ROMs), CD-recordables (CD-Rs), CD-rewritables (CD-RWs), magnetic tapes and other optical and non-optical data storage hardware units. The non-transitory computer-readable medium can include computer-readable tangible medium distributed over a network-coupled computer system so that the computer-readable code is stored and executed in a distributed fashion.

Although the method operations above were described in a specific order, it should be understood that other housekeeping operations may be performed in between operations, or operations may be adjusted so that they occur at slightly different times, or may be distributed in a system which allows the occurrence of the processing operations at various intervals associated with the processing, as long as the processing of the overlay operations are performed in the desired way.

One or more features from any embodiment may be combined with one or more features of any other embodiment without departing from the scope described in various embodiments described in the present disclosure.

Although the foregoing embodiments have been described in some detail for purposes of clarity of understanding, it will be apparent that certain changes and modifications can be practiced within the scope of the appended claims. Accordingly, the present embodiments are to be considered as illustrative and not restrictive, and the embodiments are not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

The invention claimed is:

1. A method for performing chamber-to-chamber matching, the method comprising:

executing a first test within a first plasma chamber to measure a variable, wherein the first test is executed under a condition that places the first plasma chamber in a no plasma zone;

executing a second test within a second plasma chamber to measure the variable, wherein the first and second tests are executed based on one recipe, wherein the second test is executed under a condition that places the second plasma chamber in the no plasma zone;

determining a first relationship between the variable measured with the first test and power provided during the first test;

determining a second relationship between the variable measured with the second test and power provided during the second test; and

identifying power adjustment to apply to the second plasma chamber during a subsequent processing operation based on the first and second relationships, the power adjustment causing the second plasma chamber to perform the processing operation in a processing condition determined using the first plasma chamber, wherein during the processing operation, plasma is stricken within the second plasma chamber.

2. The method of claim **1**, wherein the variable is current or voltage.

3. The method of claim **1**, wherein the variable is measured during the first test using a probe coupled to a chuck, the chuck located within the first plasma chamber.

4. The method of claim **1**, wherein the variable is measured during the second test using a probe coupled to a chuck, the chuck located within the second plasma chamber.

5. The method of claim **1**, wherein the variable is measured during the first test using a probe, the probe coupled to a point between a radio frequency (RF) generator and a wafer, the RF generator coupled via an RF cable to an impedance matching circuit, the impedance matching circuit coupled via an RF transmission line to the first plasma chamber, the wafer placed on a surface of the chuck.

6. The method of claim **1**, wherein the recipe includes a pressure within the first plasma chamber, a temperature within the first plasma chamber, power of an RF signal provided to the first plasma chamber, frequency of the RF signal, and gap between an upper electrode of the first plasma chamber and a lower electrode of the first plasma chamber.

7. The method of claim **1**, wherein the recipe includes a pressure within the second plasma chamber, a temperature within the second plasma chamber, power of an RF signal provided to the second plasma chamber, frequency of the RF signal, and gap between an upper electrode of the second plasma chamber and a lower electrode of the second plasma chamber.

8. The method of claim **1**, wherein the first relationship is a straight line.

9. The method of claim **1**, wherein the second relationship is a straight line.

10. The method of claim **1**, wherein the power adjustment is a difference between the power provided during the first test and the power provided during the second test.

11. The method of claim **1**, wherein the subsequent processing operation includes etching, deposition, or cleaning of a wafer placed within the second plasma chamber.

12. The method of claim **1**, wherein the processing condition includes a value of a function of the variable, the value achieved during the first test when an amount of the power is provided to the first plasma chamber during the first test.

13. The method of claim **1**, wherein the first plasma chamber has a higher yield than the second plasma chamber.

14. The method of claim **1**, wherein the condition that places the first plasma chamber in the no plasma zone includes an amount of pressure within the first plasma chamber to avoid striking plasma within the first plasma chamber, and wherein the condition that places the second plasma chamber in the no plasma zone includes an amount of pressure within the second plasma chamber to avoid striking plasma within the second plasma chamber.

15. A method for performing intra-chamber matching, the method comprising:

executing a first test to measure a variable associated with a plasma chamber, the plasma chamber is in a first condition during execution of the first test, wherein during execution of the first test, the plasma chamber is operated to be in a no plasma zone;

executing a second test to measure the variable associated with the plasma chamber, the plasma chamber is in a second condition during execution of the second test, wherein during execution of the second test, the plasma chamber is operated to be in the no plasma zone;

determining a first relationship between the variable measured using the first test and power provided during the first test;

determining a second relationship between the variable measured using the second test and power provided during the second test; and

identifying power adjustment to apply to the plasma chamber during a subsequent processing operation based on the first and second relationships, the power adjustment causing the plasma chamber to perform the processing operation in a processing condition, the processing condition determined when the plasma chamber is in the first condition, wherein during the processing operation, plasma is stricken within the plasma chamber.

16. The method of claim **15**, wherein the second condition occurs in time after occurrence of the first condition.

17. The method of claim **15**, wherein the second condition occurs after performing processing on a wafer placed within the plasma chamber, the first condition occurring before performing the processing.

18. A plasma system for performing chamber-to-chamber matching, the plasma system comprising:

a first plasma chamber used to execute a first test to measure a variable, wherein the first plasma chamber is configured to operate in a no plasma zone during execution of the first test;

a radio frequency (RF) transmission line coupled to the first plasma chamber for communicating an RF signal to the first plasma chamber;

an impedance matching circuit coupled to the RF transmission line;

an RF generator coupled to the impedance matching circuit for supplying an RF signal to the impedance matching circuit;

a second plasma chamber used to execute a second test to measure the variable, wherein the first and second tests are executed based on one recipe, wherein the second test is executed after decoupling the first plasma chamber from the RF transmission line and coupling the second plasma chamber to the RF transmission line, wherein the second plasma chamber is configured to operate in the no plasma zone during execution of the second test; and

a host system including a processor, the host system coupled to the RF generator, the processor configured to:

determine a first relationship between the variable measured with the first test and power provided during the first test;

determine a second relationship between the variable measured with the second test and power provided during the second test; and

identify power adjustment to apply to the second plasma chamber during a subsequent processing operation based on the first and second relationships, the power adjustment causing the second plasma chamber to perform the processing operation in a processing condition determined using the first plasma chamber.

19. A plasma system for performing intra-chamber matching, the plasma system comprising:

a plasma chamber used to execute a first test to measure a variable, the plasma chamber is in a first condition during execution of the first test, wherein the plasma chamber is configured to operate in a no plasma zone during execution of the first test,

the plasma chamber used to execute a second test to measure the variable, the plasma chamber is in a second condition during execution of the second test, wherein the plasma chamber is configured to operate in the no plasma zone during execution of the second test;

a radio frequency (RF) transmission line coupled to the plasma chamber for communicating an RF signal to the plasma chamber;

an impedance matching circuit coupled to the RF transmission line;

an RF generator coupled to the impedance matching circuit for supplying an RF signal to the impedance matching circuit; and

a host system including a processor, the host system coupled to the RF generator, the processor configured to:

determine a first relationship between the variable measured using the first test and power provided during the first test;

determine a second relationship between the variable measured using the second test and power provided during the second test; and

identify power adjustment to apply to the plasma chamber during a subsequent processing operation based on the first and second relationships, the power adjustment causing the plasma chamber to perform the processing operation in a processing condition, the processing condition determined when the plasma chamber is in the first condition.

20. The plasma system of claim **18**, wherein the first plasma chamber includes a first chuck, wherein the variable is measured during the first test using a probe coupled to the first chuck, wherein the second plasma chamber includes a second chuck, wherein the variable is measured during the second test using a probe coupled to the second chuck.

21. The plasma system of claim **18**, wherein the first plasma chamber includes a chuck, wherein the variable is measured during the first test using a probe, the probe coupled to a point between the RF generator and a wafer placed on a surface of the chuck.

22. The plasma system of claim **18**, wherein the first plasma chamber has a higher yield than the second plasma chamber.

23. The plasma system of claim **19**, wherein the plasma chamber includes a chuck, wherein the variable is measured during each of the first and second tests using a probe coupled to the chuck.

24. The plasma system of claim **19**, wherein the plasma chamber includes a chuck, wherein the variable is measured during each of the first and second tests using a probe, the probe coupled to a point between the RF generator and a wafer placed on a surface of the chuck.

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